Resolving the Paradox Between Philosophical Reasoning and Scientific Results

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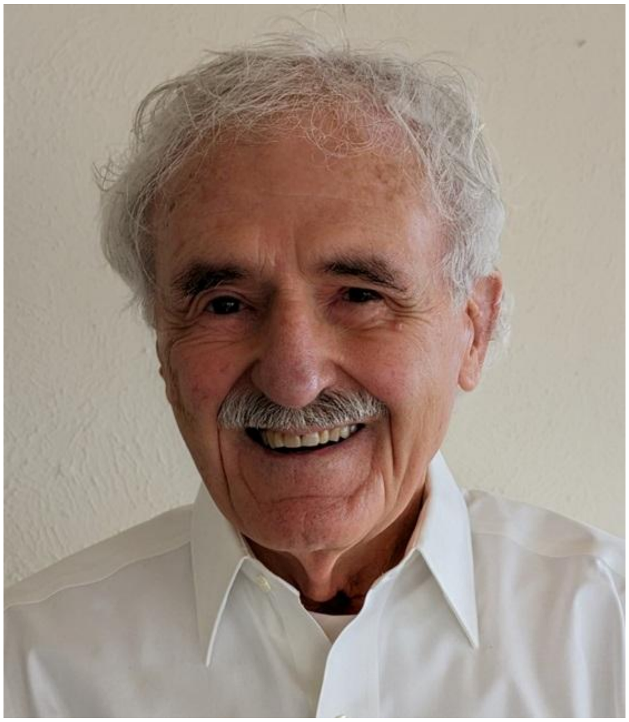

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He co-invented the method of ion fragmentation used in tandem (MS/MS) mass spectrometers which is a key instrument of biomedical science. He has received awards from the *American Society for Mass Spectrometry* and the *American Chemical Society*. He has authored over a dozen patents and hundreds of peer-reviewed articles and book chapters. He coauthored *Electronics for Scientists* with sequels and wrote *The Art and Science of Chemical Analysis*.

Teaching has been his ambition and passion since grade school and continues to be in retirement. His interest in the deeper meaning of scientific research stemmed from reading *Zen and The Art of Motorcycle Maintenance* (Pirsig 1974). Poincaré's point about there being multiple plausible explanations for any given set of observations piqued his interest in the philosophy of science. The harmful effects of science denial further fueled his study aiming at finding a logical basis for certainty in the parts of science that undergird technology. This Opinion Piece encapsulates his conclusions. They are ideas he wishes he had known while still teaching and mentoring.

More details at: www.chrisenke.net.

"Basic Principle of Physics is Wrong, Oxford Scientists Say[1]." This is the title of an article in *Newsweek*[2] reporting on an experiment[3] that found a negatively charged object attracted to a negatively charged surface. This clearly violates the law of like-charges repelling each other. In titling her article, Robyn White was following our common assumption that finding an exception to a law is a disproof of that law. The Oxford scientists made no such claim, but this view has been a fundamental plank in the philosophy of science since David Hume (1711-1776). It has been passed on in these familiar declarations: "Consistency is no proof of certainty." "You cannot guarantee what will happen tomorrow." "Any law's 'black swan' might be just around the corner." [4]

The Paradox

We widely accept this is true, but that's not how we live. We entrust our lives in countless ways to the physical, mechanical, chemical, and biomedical "laws" science has developed. We rely on technological devices in our work and leisure and for many of life's necessities. Barring parts failure or obsolescence, we expect these mechanisms to work as designed indefinitely. We don't expect discoveries of the sort described above to repeal the principles our devices are based on. On the other hand, history is rife with incorrect scientific conclusions like the geocentric solar system and the caloric theory of heat.

So clearly some aspects of science are trustworthy, and some aren't. In Philosophy, scientific realists affirm this position, but have not yet established which is which. Until this dichotomy between our behavior and our belief is settled—until we are clear about what knowledge will endure and what won't, we have no definitive answer to science skeptics. Nor can we heal the rift that developed between philosophical thought and scientific practice over the last three hundred years.

Working on an answer

While working as an academic chemist specializing in the development of novel instrumentation, I have delved into this conundrum for the past five decades. My inquiry was stimulated by Robert Pirsig's (1974) book, *Zen and the Art of Motorcycle Maintenance: An Inquiry into Values,* and has continued through study, reflection, and conversation. This has led, finally, to a logical resolution of science's success in the face of apparently irrefutable reasons for the uncertainty of its discoveries.

My proposed resolution to this centuries-old puzzle and the story of its unfolding are in my essay *Unraveling the Science/Philosophy Paradox: A Key Factor in Repairing the Divide*. It appears in the recently published book *The Divide Between Humanities and Science: Why It Matters and How it Can be Repaired*[5], edited by Richard Brusca. I have summarized its principal conclusions for this piece.

For rigor, I'll first define some terms. Our scientific knowledge of a natural phenomenon has two parts. One is the *law,* which is a statement that generalizes an observed uniformity. It expresses the relationship among its quantities and properties. Examples are $e = mc^2$, or water boils at 100° C. The law does not tell us why nature acts that way, but we naturally seek an *explanation*. The law is the *what* and the explanation is the *why*. These two parts make up our theory of a phenomenon, but sometimes we use the word theory for just the explanation. Though closely linked, the law and its explanation have distinct functions. We use the law to make predictions involving the phenomenon and we conceive an explanation to make sense of the behavior observed.

Exceptions: a bane or a boundary?

Through my study, I have come to realize that philosophers and scientists have opposing ways of treating the discovery of an exception to a law. And that this difference is a critical factor in the dichotomy of our trust in technological devices while accepting the laws they are based on are not certain. Here are two takes on the same exception. Naomi Oreskes, a science historian, in *Why Trust Science* (Oreskes 2019), says classical mechanics is now "on the scrap heap of history," undone by relativity, which proved it did not work in situations of extremely high velocity or intense gravitational fields. But

Carlo Rovelli, a physicist/philosopher, says "Einstein's theory does not falsify Newton's theory; it clarifies it by neatly specifying its domain of validity" (Rovelli 2014). One says an exception nullifies a law while the other says it just identifies situations in which it doesn't work.

It's easy to see which of these views is correct since we continue to teach Newton's laws of motion and mechanics and use them where they have always worked. Finding a condition in which a law doesn't apply prevents it from becoming a universality, *i.e.*, a law that works in every location over all time. Since the empirical verification of any law being a universality is impossible, let's give that up. But knowing the circumstances in which a law consistently works is all that is needed to assure us that will continue to be the case. *New exceptions will only be found under conditions outside the boundaries previously tested*.

The story of the like-charges attracting which opened this piece is a case in point. The experiment involves a large DNA molecule with an overall negative charge. But the subject molecule has a region in which the charge is positive. In an aqueous solution, the molecule is repelled from a negatively charged plate as expected, but in alcohol, the positively charged region has a stronger effect resulting in its attraction to the negatively charged plate. The differences in the electrical conductivities and dielectric constants of water and alcohol change the influence of the positively charged area in an understandable way. This condition, in which a fundamental law of electricity appears to be violated, won't keep our electronic devices from operating as designed.

The conclusion, then, is that our laws will continue to make correct predictions of natural behavior *when applied within the boundary of tested conditions*. They will not be undone by the discovery of exceptions. We can then safely call our empirically verified laws *bounded certainties*.

Challenges to certainties

Nancy Cartwright has raised the question about whether our laws, often demonstrated in the laboratory, actually work in the real world (Cartwright 1983). Taken alone, the laws of gravity will not predict the path of a falling leaf. Other simultaneous processes make that law's predictions inaccurate.

When scientists employ laws despite interfering processes and exceptions, they are said to be idealizing, *i.e.*, using a law that strictly speaking, they know is untrue. For example, we know that the boiling point of water is only 100° C at sea level. Angela Potochnik claims that "idealizations are rampant and unchecked in science" and by "unchecked" she means "that little effort is put forward toward eliminating or controlling these idealizations" (Potochnik 2017).

Potochnik is right if she means scientists are not doing much to reformulate idealized laws so they are "true," *i.e.*, perfectly exact. Sometimes the relationships of one or two concurrent phenomena can be built into a single equation, but now we use digital simulation to include the effects of multiple simultaneous processes. But even these methods don't eliminate all the factors that can affect our results.

Historians and philosophers of science have long elaborated on epistemological implications of idealization in science.[6] Educators have looked at the pedagogical challenges of idealization, particularly the disrupt between everyday experience and what teachers and textbooks are saying about the supposedly lawful phenomena pupils observe, measure and conjecture about.[7]

The argument that outcomes obtained in the face of these causes of deviation are not perfectly exact is correct, but are they so wrong they are not useful? Scientists handle it this way: the more precision the purpose of the measurement requires, the harder we work to control the conditions affecting reproducibility. In an article titled *True Enough*, Catherine Elgin describes how scientists determine when these deviations significantly affect the outcome, and how they compensate for them when they do (Elgin 2004).

And doing just that has been part of my work as an instrument designer. When I started in analytical chemistry, the standard was assay results having three significant digits in mixtures with a score of components.[8] Now we are doing quantitative assessments of up to six significant digits in mixtures that have thousands of components. Astronomers measure time to within fourteen significant digits. The more control we gain over the variables affecting precision, the more we learn about the process and its exceptions.

In our daily life, measurements require different levels of accuracy. Just as in science, the criterion we apply is whether the accuracy of the method is sufficient for the task. Cooking rice, we would not use a volumetric flask and a balance to get the right ratio of rice to water; a measuring cup will suffice. Spa water pH strips are crude compared to a pH meter, but they provide the information needed. From a practical standpoint, a measurement that satisfies its application is not wrong, even though it is not perfectly exact.

In some areas where we attempt to apply scientific methods, the number and significance of uncharacterized factors is too great for “laws” to provide consistent predictions. Differences in people’s biological makeup affect how they react to treatments. And in economics, psychological factors interfere with predictions based on logic. These are not failures of science. We just don’t yet have laws that include those factors. The uncontrolled variables are too many and too large.

Predicting what will work tomorrow

The final and usually fatal arrow in the quiver of uncertainty is what could happen tomorrow. The future is necessarily an untested condition. As Karl Popper says, “It is perfectly possible that the world as we know it, with all its pragmatically relevant regularities, may completely disintegrate in the next second” (Millar 1985). Imagine what would cause gravity to turn off or all molecules to revert to their atoms. Wouldn’t it be a change in conditions—a new and necessarily cataclysmic development? Popper’s scenario of when basic laws would fail supports this point: it would require a dire change in conditions. We can agree, but if what happens is severe enough to disrupt fundamental laws, we won’t be here either. So our verified laws will remain bounded certainties for as long as it matters.

What the Realists can be realistic about

Let’s pause here for a moment to consider what the above arguments have established. *The continued applicability of our laws within their verified boundaries is a certainty*. This statement represents a sea change in what we can claim to know for sure. It offers solid confirmation instead of informed opinion or broad consensus to support the reliability of predictions based on those laws.

It is gratifying to have found the part of scientific knowledge that resolves the paradox of philosophical uncertainty and scientific success, but there is still the fact that we continue to prove previously believed theories wrong. We are about to experience another major rewrite as the James Webb Space Telescope (JWST) is finding galaxies and black holes more mature than our timing of the Big Bang allows. Some deduction(s) we now embrace will have to be revised or replaced.

Explanations: essential, but fungible

So what part of our knowledge is mistaken when new data shows a theory to be wrong? It's the part we haven't talked about much yet, *i.e.*, the explanation. The data we have collected and verified is still valid, as are the bounded certainties we have generalized from them. New observations that are inconsistent with our understanding of the phenomenon tell us that the current explanation is no longer tenable. So we need to reflect on the basic nature of our explanations.

It was the following part of Persig's book that got me started on this inquiry. He quoted Henri Poincaré, the late 19th century French scientist/mathematician/philosopher.

> If a phenomenon admits of a complete mechanical explanation, it will admit of an infinity of others which will account equally well for all the peculiarities disclosed by experiment. [9]

Einstein agreed, saying[10], "other systems of thought are always conceivable which are capable of joining together the same given facts."

These quotations regarding the source of explanations were eye-opening for me. It says they do not flow inevitably or uniquely from the observations. We make them up! We find a rationalization for them that fits the observations. Richard Feynman (1918-1988), a renowned theoretical physicist, discussing our failure to find an explanation for the particle/wave duality of quantum objects, tells us how we generate explanations:

> They are attempts to make sense of our observations, analogies to processes that we're already familiar with. And when we can't find one that is satisfactory, it's a failure of our experience or imagination.[11]

When one is conceived, it might not be the only credible one. This suggests we probably shouldn't think of an explanation as being true or false. Nor do we need to apply Ockham's razor to choose the "right" explanation among plausible alternatives; they might all be useful in various contexts.

In *Surfaces and Essences*, Hofstadter and Sander tell us we have a "non-stop need" to make sense of our observations in terms of things we already know or understand.[12] They help us categorize and remember the behavior patterns we have deduced into laws, but their value is in their usefulness, not their truth.

The dual meanings of the word "theory" (a law and its explanation or just the model) can, and often has, led us to "throw the baby out with the bathwater." When an explanation is disproved, it is common to conclude that whole theory has now joined our list of mistakes. Realizing that a theory has two parts, only one of which is no longer supportable, clarifies what is still valid. Perhaps we need a new word specifically for the combination.

An important way that an explanation complements its law is in providing an answer to the impossibility of exhaustive testing. Since one can’t test every possible value of all the factors of a law in every location, how do we know there is not some specific combination of parameters within the tested boundaries in which the law fails? From empirical observations alone, this argument can’t be rebutted. But scientists don’t just rely on data. We would not propose a law that swans must be white without some genetic rationale for that conclusion. The law expresses the uniformity, and the explanation provides the means to assess whether an untested combination of factors could credibly provide such an exception.[13]

Here's an example. If you hold a book up and let it go, it will surely fall. We’re certain this will happen every time. “Unsupported books will fall toward the earth” is an expression of this uniformity. But even this obvious statement has boundaries. The book must not be moving with respect to the earth when it is released, and the book must be denser than the surrounding medium (for instance, air). But within those bounds, do we need to test this expression with every book in every location on the planet to be sure of it? No, because we have an explanation for the interaction between the book and the earth. We understand the book and the earth have mass and that masses attract each other. We can reliably predict, therefore, within known boundaries, that all unsupported books will fall toward earth.

Some explanations, on their level, are “settled” science

So far, we have categorized analogies and models as the part of scientific knowledge that later discoveries can disprove. I assumed then that all explanations were tentative until I ran across the phrase “settled science[14],” referring to a model that has been proven beyond question. On consideration, I was surprised to realize how many models or explanations within just my limited purview are settled. By “settled,” I mean by substantial empirical confirmation, not by consensus. *All our examples of theories proven false were widely believed up to their collapse*.

But there is no longer any doubt about the heliocentric model of the solar system. Photos of the earth from space, satellites sent to orbit the sun, etc. have made the heliocentric model undeniable. We have confirmed the double helix conformation of DNA by X-rays and microscopy. We have measured the velocity of tectonic plates, verifying the reality of their motion. Atoms of the chemical elements unquestionably exist and form compounds by sharing electrons with their neighbors. There are hundreds, probably thousands, of other models that are settled science. Of course, there is more to learn in all these areas as we probe more deeply into their qualities and substance. There are aspects of atoms and photons we may never understand. But at the level stated, there is much that is truly settled.

To summarize, our predictive laws are “bounded certainties”—their applicability within their tested limits is assured. The explanations for those laws are useful analogies, but they are not settled science until extensively empirically confirmed. These conclusions give solid ground for trust in predictions based on our laws. They also tell us which areas are prone to change. This understanding of scientific knowledge could affect our approach to scientific teaching and research, as well as science journalism. But not without some work. For generations, we have been schooled in the arguments against any certainty. Developing an acceptance that a part of scientific knowledge truly represents reality will be a challenge.

Guardians of the gate

The model I propose, of scientific knowledge being composed of laws and their explanations, has a parallel in everything we believe. In the broader sense, the components are belief and story. Between the two, the story is by far the more persuasive (Olson 2015). New data that conflicts with an existing explanation is often considered suspect. It's hard to give up a story that has worked until now.

I have had the fortune (or misfortune) to have made two breakthrough discoveries in mass spectrometry[15,16]. In both cases, it was my first foray into the research area. The reviews of my journal submissions included uncritical rejection of my data and interpretation, and a denial of my authority to publish on the subject[17]. Only after others adopted and credited my work were they more widely accepted. Now my revised explanations are part of the doctrine. This is an oft-repeated pattern. There are dozens of such stories, including at least one who went on to win a Nobel Prize[18]. The initial dismissals come from the guardians of the gate[19]—persons having a personal identification with the existing story.

Implications for teaching science

In the teaching of science, it is my experience that the duration of the student's retention of the material is disappointingly low. But in every development, there is a human story of how and when it came about—what they were thinking, what beliefs were displaced, what impact their creation had on science and society. Discussing these might help bridge the gap between science and the humanities and, I predict, make the subject more memorable. The phenomenon being taught would have a story. If I were still teaching, I would try that.

All the years of doing research, I did not know to separately consider the law and its explanation. I had a lot of experience with exceptions to laws, but they were just conditions to avoid or compensate for in the measurements I was making. I assumed the laws I was using were reliable, but I had no rationale for that conclusion. Nor did I know enough to hold their associated explanations more lightly. They were taught as fact, and I accepted that. If I weren't retired from research, passing on the stories of laws continuing to work even when their explanations were replaced would be part of my mentoring. In publications, I would differentiate between what was certain and what was proposed.

Presenting science to the public

There have been many calls for scientists to do a better job of communicating their results to the public. Some have done this exceedingly well. One thinks of Carl Sagan (1934-1996), Neil deGrasse-Tyson, and Carlo Rovelli. But few scientists have the platforms those exemplars developed, and few have the time or skills to exploit them. For most, the best bet is to work through science journalists to publicize their results. But it is not just the conclusions, but the stories leading up to them that can make the difference. Bringing these to the public is up to both the scientists and the journalists who follow the story.

This essay began with the report of the discovery of an interesting exception to a fundamental law. The law was not wrong as the *Newsweek* article's title claimed—it just didn't apply in that particular situation. To be fair, the magazine's editor might have come up with the unhelpful title, hoping its iconoclasm would attract more readers. Nor should I blame the author. There has been no teaching on how to distinguish the discovery of an exception from the overturning of a law. I hope some journalists reading this piece will pass on this way of characterizing scientific advancements. It is among journalists that my postings[20] on this topic have gained the greatest attention.

Telling the stories

We sometimes overlook the fact that people do science. Breakthrough ideas come from someone's creativity and imagination. There are wonderful stories associated with each of these events. We remember the stories of Lavoisier's postulation of oxygen as the agent in combustion which then led to our understanding of molecular structure, Kekule's imagination of the cyclic structure of benzene, Darwin's conception of the evolution of organic life, and Einstein's interrelatedness of space and time, and many more. These stories give life and meaning to their conclusions.

We love stories, we remember them, and sometimes they change how we think.

If you have comments, suggestions, points of dissent, please send them to me at enke@unm.edu. I would enjoy discussing them with you.

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[1] https://www.newsweek.com/basic-principle-physics-wrong-oxford -university-scientists-say-1874984

[2] Newsweek - News, Analysis, Politics, Business, Technology

[3] Wang, S., Walker-Gibbons, R, Watkins, B., Flynn, M., Krishnan, M., A Charge-dependent long-ranged force drives tailored assembly of matter in solution, *Nature Technology*, 19, 485-493, 2024

[4] How the Black Swan Became a Red Herring | Alan Alda Center for Communicating Science

[5] The Divide Between Humanities and Science: Why It Matters and How it Can be Repaired – Ethics Press

[6] See Nowak 1972, 1980, Barr 1974, Laymon 1985, McMullin 1985, Niiniluoto 1986, Appiah 2017, and Rice 2021.

[7] See Niaz 1999, Portides 2017, Matthews 2015, chap.11.

[8] Roughly put, the number of significant digits in a measurement is the number of digits, starting with the most significant, that do not change with repeated measurement. A measurement with six significant digits is precise to one part per million—with three significant digits, one part per thousand, and so forth.

[9] Poincaré, H. 1905. *Science and Hypothesis*. First English translation. Walter Scott, London. [My copy is the Dover edition, 1952]

[10] Einstein A. Induction and Deduction in Physics, Berliner Tageblatt, 25 December 1919

[11] Feynman, R. 1964. 6th Cornell lecture. https://www.feynmanlectures.caltech.edu/fml.html#6

[12] Hofstadter D. and E. Sander. 2013. *Surfaces and Essences: Analogy as the Fuel and Fire of Thinking*. Basic Books, New York

[13] (2) LDW 16 We Can't Test Every Combination of Factors

[14] https://www.quora.com/When-did-the-phrase-settled-science-start-What-is-an-example-and-why

[15] The Triple Quadrupole (MS/MS) — Chris Enke

[16] Electrospray Ionization — Chris Enke

[17] (2) LDW 21 Guardians of the Gate - by Chris Enke

[18] The Quasicrystal: The Impossible That Became Possible | The Institute for Creation Research

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[20] https://chrisenke.substack.com/

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