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ADMISSIBILITY OF SCIENTIFIC EVIDENCE UNDER *DAUBERT*: THE FATAL FLAWS OF 'FALSIFIABILITY' AND 'FALSIFICATION'

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ABSTRACT

The Daubert *mantra demands that judges, acting as gatekeepers, prevent para, pseudo or 'bad' science from infiltrating the courtroom. To do so, Judges must first determine what 'science' is, and then, what 'good science' is.*

It is submitted that Daubert *is seriously polluted with the notions of Karl Popper who sets 'falsifiability' and 'falsification' as the demarcation line between 'good' and 'bad' science. This inapt philosophy has intractably infected case law, leading to bad decisions immortalized as* stare decisis. *Among other problems is the intolerance of Popper's system for multiple causation, a key component of toxic torts. Thus, the primary objective of this work is to sanitize the philosophy of Popper from the judicial mindset before beginning to create a new gatekeeping paradigm.*

I first show that Popper's philosophy derived from, and is applicable only to, the world of quantum physics. In fact, it is totally inapt to the sciences of the courtroom: biology, chemistry and Newtonian (simple) physics. Next, I 'falsify' Popper's thesis of 'falsifiability' using scientific examples. Third, I demonstrate, both by scientific and legal example, that Popper's falsification system is unsuitable for forensic use. To my knowledge, this is the first attempt to use a science-based approach to evaluate Daubert *in a systematic fashion. Finally, with the assistance of works of the philosopher Paul Hoyningen-Huene and the scientist George Gore, I recraft the definitions of 'science' and 'good science,' highlighting the importance of verifiability, i.e., experiments*

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that produce both scientifically valid and reliable results, as separate tests.

"I will begin this book, which it is my intention to write, with an exposition of the reason why men, in their search for Truth, become involved in errors, and how these errors can be removed so that the objects of their investigations may be fully attained; moreover, why some of these errors have such a powerful hold on some people that they affirm them as the truth, deluding themselves that they know something . . . ." Saadia Gaon in Emunot V'Daot[1]

"You can't come to court in pajamas, you know!"
From 'Jonathan Bing' by Beatrice Curtis[2]

[1] DANIEL H. FRANK, SAADYA GAON, THE BOOK OF DOCTRINES AND BELIEFS, 25 (Alexander Altmann trans., Hackett Publishing 2002). *See also* Sarah Pessin, *Saadya [Saadiah],* THE STANFORD ENCYCLOPEDIA OF PHILOSOPHY (May 6, 2013), http://plato.stanford.edu/archives/fall2008/entries/saadya/ [https://perma.cc/65HW-LB2H].

[2] BEATRICE CURTIS BROWN, JONATHAN BING 10 (1936).

I. INTRODUCTION

A. Immortalized Error: The Current State of Affairs

A little over two decades ago, the United States Supreme Court handed down a decision that would profoundly change the face of scientific evidence in American courts. As it turned out, the decision would also influence legal decisions and judicial reasoning around the world.[3] The case of *Daubert v.*

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[3] Revital Hovel, *Israel's Supreme Court Rules Footprints Are Problematic Evidence,* HAARETZ (Dec. 6, 2013, 1:19 PM), http://www.haaretz.com/news/national/.premium-1.562085 [https://perma.cc/3TNL-W4ZK] (discussing the **מוראד אבו חמאד** ע"פ 02/9724 **נ'** Metzurga and Roman Zadorov cases); *see also* Morad Abu Chamad v. the State of Israel; **מ"י** פ"ד נח (1) 71.
ת"א (חי') 01/732 **תולי נ' חיפה כימיקלים בע"מ** (פורסם בנבו, 3.11.2013).
ע"א 13/6102 **עצמון נ' חיפה כימיקלים בע"מ** (פורסם בנבו, 24.9.2015).
ניקולאי מצגורה נ' מדינת ישראל 10/1620 ע"פ (פורסם בנבו) (3.12); World Intellectual Property Organization (WIPO), *Tort Ordinance (New Version) of Israel* (as amended March 2015), http://www.wipo.int/wipolex/en/text.jsp?file_id=345894 [https://perma.cc/KK25-MFLD] ("Subject to the Interpretation Ordinance, this Ordinance will be interpreted in accordance with the principles of legal interpretation obtaining in England, and expressions used in it will be presumed, so far as is consistent with their context, and except as may be otherwise expressly provided, to be used with the meaning attaching to the corresponding expressions in English law and will be construed in accordance therewith."). In 2005 the Law Commission for England and Wales proposed a *Daubert*-like criterion to help reform the law of evidence regarding the admissibility of scientific evidence. "Judges are not well-placed to determine scientific validity without input from scientists. We recommend that one of the first tasks of the Forensic Science Advisory Council be to develop a 'gate-keeping' test for expert evidence. This should be done in partnership with judges, scientists and other key players in the criminal justice system, and should build on the US *Daubert* test." FORENSIC SCIENCE ON TRIAL, HOUSE OF COMMONS SCIENCE AND TECHNOLOGY LAW, HC 96-I, at 88 (2005) (although the U.K. report mostly focused on criminal usage of the concept, clearly the *Daubert* philosophy has infiltrated British thinking, and by implication affected Israeli law as well); *see generally* Chris Miller, *Causation in Personal Injury: Legal or Epidemiological Common Sense*? 26 LEGAL STUDIES 544 (2006) (summarizing *Daubert* under the British Canadian and Australian law).

Merrell Dow Pharmaceuticals concerned the admissibility of scientific (medical and epidemiological) evidence to establish causation in a civil case.[4] Nevertheless, some say *Daubert*'s most profound effects concerned the use (or misuse) of scientific evidence in the criminal courts,[5] a concern echoed by Justice Scalia in *Commonwealth v. Menlendez-Diaz*.[6]

The actual consequence of *Daubert* was to confer upon judges the roles of gatekeepers of scientific evidence.[7] The newly empowered judges were now charged with preventing pseudo or parascientific evidence (or what some call 'junk-science')[8] from infiltrating the courtroom and tainting legal decisions. Thus, much like the guards to the palace visited by the fictional Jonathan Bing,[9] judges are now tasked with keeping riffraff and other unsuitable prospective (evidentiary) candidates from presentation at court. However, unlike the palace guards vetting Mr. Bing—who had at least had some objective, albeit superficial criteria to evaluate his suitability—*Daubert* leaves judges, who are generally unversed in,[10] and even averse to, the sciences[11]

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[4] Daubert v. Merrell Dow Pharms., Inc., 509 U.S. 579 (1993) (addressing the scientific viability of epidemiological (and other) evidence to establish that Bendectin, a drug administered during pregnancy to reduce/prevent nausea caused birth defects).

[5] *See generally* COMM. ON IDENTIFYING THE NEEDS OF THE FORENSIC SCI. COMTY. STRENGTHENING FORENSIC SCI. IN THE UNITED STATES: A PATH FORWARD 183-191(Nat'l Research Council of the Nat'l Academies Press 2009) [hereinafter STRENGTHENING FORENSIC SCIENCE] (running 254 pages and cataloging at least a dozen problems related to criminal cases).

[6] Melendez-Diaz v. Massachusetts, 557 U.S. 305 (2009) (Justice Scalia wrote for the majority).

[7] *Daubert*, 509 U.S. at 592-93 ("Faced with a proffer of expert scientific testimony, then, the trial judge, must determine at the outset, pursuant to Rule 104(a), whether the . . . [testimony's underlying] . . . . reasoning or methodology . . . is scientifically valid . . . [and] properly can be applied to the facts in issue.").

[8] I define 'junk science' using product liability parameters, i.e., as a defective product, which is "dangerous and unfit for the use intended." Steven Milloy defines 'junk science' thusly: "What exactly is junk science? In a word, fraud. In a sentence, it's faulty scientific data and analysis used to advance a special interest." STEVEN J. MILLOY, JUNK SCIENCE JUDO: SELF-DEFENSE AGAINST HEALTH SCARES AND SCAMS 1 (Cato Institute 2001). *See generally* Gary Edmond & David Mercer, *Trashing "Junk Science,"* 1998 STAN. TECH. L. REV. 3 (1998).

[9] BROWN, *supra* note 2, at 9-10 (1936). *See* Appendix.

[10] Today's judges seem more antithetical to science than their peers 100 years ago when Louis Brandeis submitted a one hundred page brief to the Supreme Court that (with the exception of two pages) predicated entirely on scientific evidence. *See* Muller v. State of Oregon, 208 U.S. 412 (1908); Ruth Bader Ginsburg, Muller v. Oregon*: One Hundred Years Later*, 45 WILLAMETTE L. REV. 359, 362 (2009) (discussing "information that would ultimately fill 98 of the 113 pages in Brandeis brief [and that] . . . only two pages of his brief presented formal legal analysis.").

[11] *See generally* LLOYD DIXON & BRIAN GILL, CHANGES IN THE STANDARDS FOR ADMITTING EXPERT EVIDENCE IN FEDERAL CIVIL CASES SINCE THE *DAUBERT* DECISION

without clear guidance or ample criteria upon which to predicate their decisions.[12]

After commanding the judiciary to vet scientific evidence according to a litany of vague precepts, the *Daubert* court remanded the case back to the Ninth Circuit to fulfill this directive. Skittish over their ability to carry out their assigned task, the Circuit judges intrepidly proceeded, but not before issuing an alert:

> As we read the Supreme Court's teaching in *Daubert*, therefore, though we are largely untrained in science and certainly no match for any of the witnesses whose testimony we are reviewing. . . . Our responsibility, then, . . . is to resolve disputes among respected, well-credentialed scientists . . . in areas where there is no scientific consensus as to what is and what is not "good science," and occasionally to reject such expert testimony because it was not "derived by the scientific method." Mindful of our position in the hierarchy of the federal judiciary, we take a deep breath and proceed with this heady task.[13]

Even in the face of their acknowledged limitations, however, the Ninth Circuit judges were remarkably clear on what they were expected to do, noting: "First, we must determine nothing less than whether the experts' testimony reflects 'scientific knowledge,' whether their findings are 'derived by the scientific method,' and whether their work product amounts to 'good science.'"[14] The judges knew *what* to do, it was how they were to do it that flummoxed them. Although the Supreme Court did suggest some *ad hoc* admissibility tests, such as peer review and publication,[15] critics complain that "appearance" tests, such as publication,[16] are no more useful arbiters of

(2001); Susan Haack, *Trial and Error: The Supreme Court's Philosophy of Science*, 95 AM. J. PUB. HEALTH S66, S67 (2005), http://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.2004.044529 [https://perma.cc/Z2QC-BGNW].

[12] Various surveys and empirical studies found that judges did not have a good understanding of the *Daubert* standards or how to apply them. *See generally* Barbara P. Billauer, Daubert *Debunked: A History of Legal Retrogression and the Need to Reassess "Scientific Admissibility,"* 21 SUFFOLK J. TRIAL & APP. ADVOC. 1 (2016).

[13] KATHERINE HUNT FEDERLE, CHILDREN AND THE LAW: AN INTERDISCIPLINARY APPROACH WITH CASES, MATERIALS AND COMMENTS 52 (2012) (citing Daubert v. Merrell Dow Pharms., Inc., 43 F.3d 1311, 1316 (9th Cir. 1995)).

[14] Daubert v. Merrell Dow Pharms., Inc., 43 F.3d 1311, 1315 (9th Cir. 1995).

[15] One "pertinent [but non dispositive] consideration is whether the theory or technique has been subjected to peer review and publication . . . . Additionally, in the case of a particular scientific technique, the court ordinarily should consider the known or potential rate of error . . . and the existence and maintenance of standards controlling the technique's operation . . . . Finally 'general acceptance' can yet have a bearing on the inquiry . . . . The inquiry envisioned by Rule 702 is, we emphasize, a flexible one." Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579, 593–94 (1993).

[16] *Id*. at 593 ("Publication (which is but one element of peer review) is not a *sine qua*

admissibility than Mr. Bing's outfits. Philosophers[17]and scientists alike agree.[18] As one noted scientist wrote:

> As in the past, our beliefs have been largely founded upon appearances, and have many of them been reversed by deeper knowledge, so may we reasonably expect, in accordance with the principle of uniformity of nature that the same process will continue to operate in the future, and that even some of our most attractive beliefs (excepting those which are logically absolute which are demonstrable in science) will suffer a similar fate.[19]

Thus,

> When agreement about what constitutes scientific knowledge can range so widely . . . it is not easy to come up with a workable alternative to the *Frye* test, which requires the judge to be an arbiter of views of practicing scientists. Trying to decide which expert is reasoning properly seems a rather difficult task for a court when even scientists often disagree how to do it.[20]

To redress the problem, a surfeit of law review articles purporting to understand how science is practiced or what 'science' is have been authored, establishing only more disagreement and error.[21] A quick Lexis search of law review articles and commentary yielded 999 entries, while a Google search produced 127,000 hits[22] with over 800 published appellate court decisions.[23] The prolix of legal commentary is mostly an unenlightened reiteration[24] of *Daubert* precepts without critical analysis[25] or articulation of useful and

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non of admissibility; it does not necessarily correlate with reliability . . . and in some instances well-grounded but innovative theories will not have been published.").

[17] BERTRAND RUSSELL, THE PROBLEMS OF PHILOSOPHY, Gutenberg files, ch. 1, *available at* http://www.gutenberg.org/files/5827/5827-h/5827-h.htm#link2HCH0001 [https://perma.cc/3BXA-7XQ8].

[18] *See generally* GEORGE GORE, THE ART OF SCIENTIFIC DISCOVERY (1878).

[19] *Id.* at 102.

[20] Jan Beyea & Daniel Berger, *Scientific Misconceptions Among* Daubert *Gatekeepers: The Need for Reform of Expert Review Procedures*, 64 LAW & CONTEMP. PROBS. 327, 335 (2001).

[21] *See* Billauer, *supra* note 12.

[22] Twerski and Sapir found 3929 results in the Westlaw database for "*Daubert v. Merrell Dow Pharmaceuticals*" with the search limited to "Secondary Sources, Law Reviews and Journals." Aaron D. Twerski & Lior Sapir, *Sufficiency of the Evidence Does Not Meet* Daubert *Standards: A Critique of the Green-Sanders Proposal*, 23 WIDENER L.J. 641, 641 n.1 (2014).

[23] This figure is as of 2010. *DAUBERT* ON THE WEB, http:/ www.daubertontheweb.com [https://perma.cc/9C7G-QXQG].

[24] SHEILA JASANOFF, SCIENCE AT THE BAR: LAW, SCIENCE AND TECHNOLOGY IN AMERICA 272 (Harvard University Press 2009) (criticizing Ayala and Black).

[25] Richard Bjur & James T. Richardson, *Expert Testimony Involving Chemists and*

practical tools. So bereft of guidance are the judges and so perplexing has the issue become, that the latest law review article appearing as of the date of this writing suggested turning the question over to computers.[26]

In addition to the problems of making *Daubert* work, we also have a proliferation of diametrically opposite opinions over its effect: some claiming *Daubert* has overly excluded evidence;[27] others claiming *Daubert* has relaxed standards of admissibility.[28] Both sides are adamant—and partisan.[29]

Some academics claim that the decision "has led to the exclusion of experts in hundreds, perhaps thousands of cases,"[30] and have proposed solutions to remedy this claimed over-exclusion: Michael Green and Joseph Sanders propose substituting a 'sufficiency' standard, ostensibly focused on evaluating the totality of evidence submitted by plaintiff,[31] instead of the methodology as enunciated in *Daubert* which, I claim, subjects each individual proffer to scientific and evidentiary scrutiny.

Other academics refute this interpretation.[32] Twerski and Sapir, Green and Sander's opponents, advocate strict adherence to *Daubert.* They are concerned that substituting Green's amalgamated approach (i.e., sufficiency) for the

Chemistry, in EXPERT WITNESSING: EXPLAINING AND UNDERSTANDING SCIENCE 79 (Carl Meyer ed., 1998) (quoting Ayala and Black, saying "Indeed, many scientists consider falsifiability the most important characteristic separating science from other forms of knowledge."); *id*. at 82 (quoting Ayala, who claims "science is socially constructed.").

[26] Pamela S. Katz, *Expert Robot: Using Artificial Intelligence to Assist Judges in Admitting Scientific Expert Testimony*, 24 ALB. L.J. SCI. & TECH. 1, 3 (2014).

[27] A backlash seeking to loosen admissibility is based on claims from plaintiffs' lawyers that a 2001 Rand study found that 90% of the courtroom uses of Frye and Daubert were anti-plaintiff. Mark R. Bower, *Erb's Palsy Junk Science Debunked by NY Appellate Court (Defendants Get Their Comeuppance)*, N.Y. PERS. INJURY ATTORNEY BLOG (Feb. 15, 2012, 9:15 AM), http://www.newyorkpersonalinjuryattorneyblog.com/2012/02/junk-science-debunked-by-ny-appellate-court-defendants-get-their-comeuppance.html [https://perma.cc/AR5S-X5XP].

[28] Michael D. Green & Joseph Sanders, ADMISSIBILITY VERSUS SUFFICIENCY: CONTROLLING THE QUALITY OF EXPERT WITNESS TESTIMONY IN THE UNITED STATES (Wake Forest Univ. Sch. of Law Legal Studies Research Paper Series, Paper No. 2016468 & Univ. of Houston Law Ctr., Pub. Law and Legal Theory Research Paper Series, Paper No. 2016468), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2016468.

[29] *See generally* Billauer, *supra* note 12.

[30] Green & Sanders, *supra* note 28.

[31] *Id*.

[32] Heather Isringhausen Gvillo, *Asbestos Experts Argue on Role of* Daubert *Factors in Asbestos Litigation*, LEGAL NEWSLINE (Oct. 29, 2014), http://legalnewsline.com/issues/asbestos/252973-asbestos-experts-argue-on-role-of-daubert-factors-in-asbestos-litigation [https://perma.cc/47S3-UZLV] (reporting on a symposium at Widener University School of Law, "The dispute arose out of an article written by . . . Michael Green and . . . Joseph Sanders titled Admissibility Versus Sufficiency: Controlling the Quality of Expert Witness Testimony in the United States[.]").

paradigm set forth in *Daubert* will eviscerate its purpose.[33] Even changing the name of the standard bothers Twerski and Sapir, who are concerned that nomenclature influences thought.[34] Twerski and Sapir make a compelling case that junk science has found its way into court, even post-*Daubert*.[35] Rather than focusing on refining a methodology to preempt such practice, however, Twerski and Sapir claim that preserving strict adherence to *Daubert* as it stands will preclude continuing abuses.[36]

It bears consideration that any partisan bias,[37] if it does exist,[38] could be due to factors other than *Daubert's* directives,[39] such as more judges taking judicial training courses or availing themselves of greater educational or expert resources. Such factors are often ignored by the partisan flag-bearers. It is also possible that *Daubert* is indirectly influencing admissibility as a consequence of scientific errors or misunderstandings that have crept into case law over the years, and are now embedded as binding precedent.[40] This possibility has been completely overlooked in the *Daubert* analysis.

In any event, it is beyond reasonable doubt that *Daubert* is broken.[41] I

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[33] Twerski & Sapir, *supra* note 22, at 642.

[34] *Id*. at 670.

[35] *Id.* at 646.

[36] *See generally id*.

[37] However, if a positive finding exists, it may not be due to *Daubert per se*, but to other confounding factors, e.g., political biases of decision-makers reflecting those of the President appointing her/him. *See* Adam Liptak, *Why Judges Tilt to the Right*, N.Y. TIMES (Jan. 31, 2015), http://www.nytimes.com/2015/02/01/sunday-review/why-judges-tilt-to-the-right.html [https://perma.cc/6SAG-9TEE] (commenting on Lee Epstein, William M. Landes and Judge Richard Posner); *see also* Erik C. Nisbet et al., *The Partisan Brain: How Dissonant Science Messages Lead Conservatives and Liberals to (Dis)Trust Science*, 658 ANNALS AM. ACAD. POL. & SOC. SCI. 36-66 (Mar. 2015).

[38] A careful review of the Rand Study reveals the claimed favoritism towards plaintiffs is misleading. Compared to 1980-89, the most recently available post-*Daubert* findings actually benefited plaintiffs. Further, the majority of the anti-plaintiff findings were NOT in medical, health or technological areas. *See generally* Billauer, *supra* note 12.

[39] Anecdotal experience leads me to conclude that judges' decisions on admissibility often turn on the Judge's innate phobia or interest in science; those interested being more likely to hold *Daubert* hearings; the science-averse being more likely to let the jury (who in all probability is far less science-averse than the Judge) decide.

[40] *E.g.*, Manko v. United States, 636 F. Supp. 1419 (W.D. Mo. 1986), *aff'd,* 830 F.2d. 831 (8th Cir. 1987).

[41] In 2011 (as well as 2002) the Federal Rules of Evidence were amended to redress some of these concerns. *See* Letter from Chief Justice Roberts to President Obama (Apr. 26, 2011), http://www.supremecourt.gov/orders/courtorders/frev11.pdf [https://perma.cc/HKM6-MB7S] (letter provides proposed changes submitted to Congress). Some issues were also dealt with in the *Kumho* and *Joiner* cases, which, along with *Daubert*, are often referred to as the '*Daubert* Trilogy.' Nevertheless, the issue of what exactly constitutes 'science' and *Daubert's* reliance on Popper's definition of falsifiability is never reviewed nor has it been revoked—and hence remains viable as *obiter dicta*.

submit that substituting one fuzzy and composite test (sufficiency)[42] for a hodge-podge of tests based on uninformed science-speak (e.g., the enumerated *Daubert* tests) only confounds and compounds the problem. Thus, rather than arbitrarily weakening the standard as Green and Sanders suggest, or maintaining the status quo as Twerski and Sapir argue, I suggest that a different approach, a simplified, cohesive method predicated on relevant (i.e., courtroom-related) science[43] and how it is practiced by scientists, rather than by philosophers masquerading as scientists, the approach used in *Daubert*. Further, rather than adopting and bastardizing alien words with particular technical nuances (e.g., reliability[44] and validity), I suggest that casting the scientific method in familiar legal language, such as materiality and competency, might be more lawyer-friendly.

B. The Errors Daubert *Wrought*

Before creating a new judicial gatekeeping paradigm, we must first agree that relevant science of the courtroom arises from biology, chemistry and (simple) Newtonian physics.[45] Considerations of the rarified world of quantum physics—which may explain how the Universe was born—are inapplicable to matters relating to human activity, i.e., the subject of lawsuits.[46] It is the trajectories of bullets and the torque of a screw, which fall under the rubric of Newtonian physics that are involved in litigation—not Einsteinian physics and relativity. It is the care of the obstetrician birthing a baby that instigates lawsuits, not the mathematical musings of theoretical physicists regarding how

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[42] Lisa Heinzerling, *Doubting* Daubert, 14 J.L. & POL'Y 65–83 (2006).

[43] *See* Method And System For Providing Interactive Legal Training, U.S. Patent No. 20,070,048,720 (issued Mar. 1, 2007), http://patents.justia.com/patent/20070048720 [https://perma.cc/W7FM-59EG] (This patent was issued to the author.).

[44] *See generally*, Haack, *Trial and Error*, *supra* note 11, at S66-75; *see also* Lloyd Dixon & Brian Gill, *Changes in the Standards for Admitting Expert Evidence in Federal Civil Cases Since the* Daubert *Decision*, RAND INSTITUTE FOR CIVIL JUSTICE (2001), http://www.rand.org/content/dam/rand/pubs/monograph_reports/2005/MR1439.pdf [https://perma.cc/G8P4-VNAX].

[45] While Newtonian physics is 'wrong' (per Roger Penrose, in ROGER PENROSE ET AL., THE LARGE, THE SMALL AND THE HUMAN MIND (Cambridge Univ. Press 2000)), the results are apparently off by a factor of 10^{14}. I suggest we can safely say they are 'reliable or precise enough.' This appears to be the view of Justice Breyer, who wrote that "a courtroom is not a scientific laboratory, and hence the objective of the judge must be "to seek decisions that fall within the boundaries of scientifically sound knowledge and *approximately* reflect the scientific state of the art." Stephen Breyer, *The Interdependence of Science and Law*, 280 SCIENCE 537–38 (Apr. 24, 1998) (emphasis added).

[46] Some say "Newtonian physics is off by almost one percent, with all possible excuses for the discrepancy having been eliminated." *See* Hubert L. Bray And Marcus A. Khuri, *P.D.E.'s Which Imply the Penrose Conjecture*, 15 ASIAN J. MATH 557, 558 (2011), http://www.math.duke.edu/~bray/PE/euclid.ajm.1331583349.pdf [https://perma.cc/8XNQ-5XHG].

the Earth was born. This may seem rudimentary, however, one conclusion of this paper is that the root of the *Daubert*-dilemmas derives from misappropriation of philosophies associated with cosmological constants, quantum constraints and other curious considerations of physics which are irrelevant in the courtroom.

In redressing the problems, a deconstruction of *Daubert* is necessary. This article will raise five issues arising from the case, which culminate in five problems now enshrined as precedent. In this paper, I discuss the first two of these issues and corresponding errors in depth, and touch on the third and fourth.

The Five *Daubert* Issues:

1. What is 'science'?
2. What is 'good science'?
3. What is the scientific method?
4. What constitutes adequate scientific proof of 'good science'?
5. What are the standards and burdens of proof?
6. How do we prove scientific causation post-*Joiner*?[47]
7. What 'novel science' is sufficiently 'scientific' to pass evidentiary muster?

The Five *Daubert* Errors: Simply stated, *Daubert* says or implies that:

1. 'Science' is theories that can be falsified (tested and proven false)
2. 'Good science' is 'science' which has been tested and not falsified; (at least not yet)
3. The 'scientific method' is based on deductive reasoning
4. Validity and reliability are no different from a 'hen's kick'[48]
5. Reliance solely on peer review is an acceptable method to evaluate novel science.

I submit these conclusions are wrong. Plain wrong—at least for those scientific issues likely to confront a court. I further argue that these flawed conclusions have negatively impacted the law, causing significant scientific errors to be enshrined under the guise of precedent,[49] and that this has

[47] Gen. Elect. Co. v. Joiner, 522 U.S. 136 (1997).

[48] *See* Daubert v. Merrell Dow Pharms., Inc., 509 U.S. 579, 590 n.9 (1993) ("the difference between accuracy, validity and reliability may be such that each is distinct from the other by no more than a hen's kick") (quoting James E. Starrs, Frye v. United States*, Restructured and Revitalized: A Proposal to Amend Federal Evidence Standard Rule* 702, 26 JURIMETRICS J. 249, 256 (1986)).

[49] STRENGTHENING FORENSIC SCIENCE, *supra* note 5 at 107–08 ("Courts often 'affirm admissibility citing earlier decisions rather than facts established at a hearing.' Much

generated such bizarre holdings,[50] such that relying on *Daubert* has itself perpetuated junk science,[51]self-replicated in the form of *stare decisis*.[52]

By way of example, in *United States v. Green,* Judge Gertner acknowledged that tool- mark identification testimony ought not be considered admissible under *Daubert*.[53] He went on to explain, however, that "the problem for the defense is that every single court post-*Daubert* has admitted this testimony, sometimes without any searching review, much less a hearing."[54] The judge felt bound to admit the testimony based on legal precedent, even though he believed it to be scientifically unsound.[55]

C. Objectives

I demonstrate here that the theoretical underpinnings of *Daubert*—namely its reliance on the philosophy of Karl Popper—are flawed,[56] although I am hardly the first to do so.[57] Professor Susan Haack has admirably and

forensic evidence—including, for example, bite marks and firearm and tool mark identifications—is introduced in criminal trials without any meaningful scientific validation, determination of error rates, or reliability testing to explain the limits of the discipline.").

[50] *See* Manko v. United States, 636 F. Supp. 1419, 1434 (W.D. Mo. 1986) (*aff'd in relevant part* by Manko v. United States, 830 F.2d 831 (8th Cir. 1987) (holding that a relative risk of 2 is equivalent to "more probable than not" causation)). Later courts produced a policy-based rationale: "The use of scientifically reliable epidemiological studies and the requirement of more than a doubling of the risk strikes a balance between the needs of the legal system and the limits of science." *See also* Merrell Dow Pharms., Inc. v. Havner, 953 S.W.2d 706, 718 (Tex. 1997).

[51] Paul C. Giannelli, *Ballistics Evidence Under Fire*, 25 CRIM. JUST. 50 (2011).

[52] Judge Gertner (in *United States v. Green,* 405 F. Supp. 2d. 104 (D. Mass. 2005)) specifically admitted that, "I reluctantly [admit the evidence] because of my confidence that any other decision will be rejected by appellate courts, in light of precedents across the country, regardless of the findings I have made." STRENGTHENING FORENSIC SCIENCE, *supra* note 5, at 108.

[53] United States v. Green, 405 F. Supp. 2d 104 (D. Mass. 2005).

[54] In *United States v. Glynn*, 578 F. Supp. 2d 567, 571 (S.D.N.Y. 2008), Judge Rakoff precluded testimony that a bullet and shell casings came from a firearm linked to the defendant because "whatever else ballistics identification analysis could be called, it could not fairly be called 'science.'" *See* STRENGTHENING FORENSIC SCIENCE, *supra* note 5, 108 n.82.

[55] *See* STRENGTHENING FORENSIC SCIENCE, *supra* note 5, 108 n.82 (citing United States v. Diaz, No. 05-CR-167, 2007 WL 485967, at *14 (N.D. Cal. Feb. 12, 2007)).

[56] NICHOLAS DYKES, A TANGLED WEB OF GUESSES: A CRITICAL ASSESSMENT OF THE PHILOSOPHY OF KARL POPPER 3, 38 (1996), http://www.libertarian.co.uk/lapubs/philn/philn037.pdf [https://perma.cc/R8LN-E6Q6].

[57] *See generally* Nicholas Dykes, *Debunking Popper*: *A Critique of Karl Popper's Critical Rationalism*, 24 REASON PAPERS 5, 5–25 (Tibor R. Machan, ed., 1999); *also available at* PHILOSOPHICAL NOTES NO. 65 (2003) http://www.libertarian.co.uk/lapubs/philn/philn065.htm [https://perma.cc/3XMD-SV3W].

comprehensively addressed the issue from a philosophical standpoint.[58] This is the first paper, however, that aims to debunk *Daubert's* integration of Popper's philosophy of science via a systematic use of scientific reasoning and examples.

To accomplish this, I first show that *Daubert's* mis-reliance on Popper's views of science, and especially his insistence on falsification and falsifiability as the criteria to evaluate what is 'science,' is patently incompatible with relevant forensic science (i.e., biology, chemistry and (simple) Newtonian physics).[59] Second, I falsify the concept of 'falsifiability.' Third, I demonstrate that Popper's view of science is incompatible with legal theories, such as joint or multi-causation, substantial causation, the burden of proof and situations where identifying the causal actor is impossible.[60] Finally, I propose an alternative view of what is 'science' and what is 'good science.'

Regardless of its flaws, one must acknowledge the noble intentions of the *Daubert* Court. With the sophisticated science relevant to today's litigation, (e.g., genetic engineering, cloning technology and birth defect causation, for which we are wanting in understanding) pseudoscientific or parascientific explanations (testimony) may easily be confused with the real thing.[61] While pseudo-sciences have contributed to societal advance,[62] even promoting our understanding of the universe,[63,64] we must guard against the temptation to consider intriguing, but unsubstantiated, research[65] as scientific even if

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[58] SUSAN HAACK, EVIDENCE MATTERS: SCIENCE, PROOF AND TRUTH IN THE LAW 139 n.76 (Cambridge Univ. Press 2014).

[59] Recently, even modern physicists are expressing disapproval with Popper's views. *See* Natalie Wolchover, *A Fight for the Soul of Science,* QUANTA MAGAZINE (Dec. 16, 2015), https://www.quantamagazine.org/20151216-physicists-and-philosophers-debate-the-boundaries-of-science/ [https://perma.cc/M2FE-FZNR]; *see also infra* notes 113 and 114.

[60] *See* Sindell v. Abbott Labs., 607 P.2d 924 (Cal. 1980); Summers v. Tice, 199 P.2d 1 (Cal.1948); Ybarra v. Spangard, 154 P.2d 687 (Cal. 1944).

[61] STRENGTHENING FORENSIC SCIENCE, *supra* note 5, at 93-4 nn.40-41 (citing FED. R. EVID. 702 Advisory Committee's Note (2000 Amendments) ("*Daubert*'s general acceptance factor does not 'help show that an expert's testimony is reliable where the discipline itself lacks reliability, as for example, theories grounded in any so-called generally accepted principles of astrology or necromancy.'")).

[62] J.D. BERNAL, A HISTORY OF CLASSICAL PHYSICS: FROM ANTIQUITY TO THE QUANTUM 249 (Barnes & Noble Books 1997); KARL POPPER, CONJECTURES AND REFUTATIONS: THE GROWTH OF SCIENTIFIC KNOWLEDGE 44 (Routledge Classics 2002) (stating that "science often errs, and . . . pseudo-science may happen to stumble on the truth.").

[63] Johannes Kepler, one of the most important scientists of all time, made his living as a fortune-teller! GORE, *supra* note 18 at 264.

[64] KARL POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY 16, 315-6 (Routledge Classics 2002).

[65] Sterling v. Velsicol Chem. Corp., 855 F.2d 1188, 1208 (6th Cir. 1988) (rejecting testimony based on an unrecognized field of "clinical ecology").

produced by reputable scientists,[66] ever-mindful that gatekeepers without rudimentary schooling in science and technology[67] are especially vulnerable to persuasion by the superficial: fancy titles, alphabet strings of degrees or distinguished grey-beards. We begin our mission, then, by examining what 'science' is according to Popper as relied on by *Daubert.*

II. FALSIFYING FALSIFIABILITY

A. Science 101 According to Daubert

'Science,' according to the ancients, simply means 'knowledge.'[68] But the *Daubert* Court ultimately has a different take. The Court began by telling us that 'scientific' implies grounding in the methods and procedure of science, that 'knowledge' connotes more than subjective belief or unsupported speculation and that the term 'science' "applies to any body of known facts or to any body of ideas inferred from such facts or *accepted as truths* on good grounds."[69] So far, so good. But then the Court reverses itself, explaining that:

> Science is *not* an encyclopedic body of knowledge about the universe. Instead, it represents a *process* for proposing and refining theoretical explanations about the world that are subject to further testing and refinement. . . . Indeed, scientists do not assert that they know what is immutably 'true'—they are committed to searching for new, *temporary* theories to explain, as best they can, phenomena . . . .[70]

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[66] *See* Brian McMahon et al., *Coffee and Cancer of the Pancreas*, 304 NEW ENG. J. MED. 630 (1981).

[67] STRENGTHENING FORENSIC SCIENCE, *supra* note 5, at 12 ("The judicial system is encumbered by, among other things, judges and lawyers who generally lack the scientific expertise necessary to comprehend and evaluate forensic evidence in an informed manner . . . .").

[68] MORRIS R. COHEN & ERNEST NAGEL, AN INTRODUCTION TO LOGIC AND SCIENTIFIC METHOD, 191 n.1 (Harcourt, Brace & Co. 1934) ("The German *Wisssenschaft* is still used to mean both knowledge and science."); 24 ENCYCLOPÆDIA BRITANNICA 396 (11th ed. 1911) ("Science (Lat. *scientia*, from *scire*, to learn, know), a word which, in its broadest sense, is synonymous with learning and knowledge. . . . For our purpose, science may be defined as ordered knowledge of natural phenomena and of the relations between them; thus it is a short term for 'natural science,' and as such is used here technically in conformity with a general modern convention."); *The Deeper Hebrew Meaning of the Biblical 'Tree of Knowledge*,' LEARN HEBREW WITH ARIEL (Dec. 30, 2015), https://hebrewwithariel.com/2015/12/30/the-deeper-hebrew-meaning-of-the-biblical-tree-of-knowledge-2/ [https://perma.cc/JHH2-NFNZ] (The words for knowledge in Hebrew "Yedah" and science "Madah" derive from the same root).

[69] Daubert v. Merrell Dow Pharms., Inc., 509 U.S. 579, 590 (1993) (emphasis added).

[70] *Id.* (emphasis added). Similarly, the word "knowledge" connotes more than subjective belief or unsupported speculation. The term "applies to any body of known facts or to any body of ideas inferred from such facts or accepted as truths on good grounds." WEBSTER'S THIRD NEW INTERNATIONAL DICTIONARY 1252 (1986).

For good measure, the court cites others who echo similar sentiments:

> Of course, it would be unreasonable to conclude that the subject of scientific testimony must be "known" to a certainty; arguably, there are no certainties in science. . . . ("Indeed, scientists do not assert that they know what is immutably 'true' -- they are committed to searching for new, temporary, theories to explain, as best they can, phenomena") . . . .[71]

Getting further bollixed up, the *Daubert* Court goes on to reformulate its view of 'science' (as the foundation stone of admissibility) based on the beliefs of the philosopher Karl Popper[72] as dubiously represented[73] by Michael Green.[74] Clearly, however, neither the court (nor its law clerks) read Popper (either in whole or in part), as his views on science directly contravene the view initially espoused by the Court. To wit:

> We must *not* look upon science as a "body of knowledge," but rather a system of hypotheses; that is to say, as a system of guesses or anticipations, which in principle cannot be justified . . . but which we work as long as they stand up to tests, and of which we are never justified in saying that we know that they are "true" or "more or less certain," or even "probable."[75]

First, then, the court rejects the notion of speculative statements as science noting that "Similarly, the word 'knowledge' connotes more than subjective belief or unsupported speculation,"[76] and then it turns around and embraces the views of Karl Popper[77]—whose very notion of science is that it *only* includes speculative hypotheses or conjectures—speculations which cannot even be

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[71] *Id*. (quoting Brief for Nicolaas Bloembergen et al. as Amici Curiae Supporting Respondents, *Daubert*, 509 U.S. 579 (No. 92-102), at 9) (citing Brief for the American Ass'n for the Advancement of Science et al. as Amici Curiae Supporting Respondent, *Daubert*, 509 U.S. 579 (No. 92-102), 1993 WL 13006281, *7-8 ("Science is not an encyclopedic body of knowledge about the universe. Instead, it represents a *process* for proposing and refining theoretical explanations about the world that are subject to further testing and refinement").

[72] *See* KARL POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 318.

[73] Professor Haack not only accuses Green of misunderstanding Popper, but also alludes to the possibility that Green never actually read Popper in the original, only summarized in an article by David Faigman. This would mean that the current legal view of science may be based on triple hearsay: the court relied on Green who relied on Faigman who relied on Popper. *See* HAACK, *supra* note 58, at 139 n.76.

[74] Michael D. Green, *Expert Witnesses and Sufficiency of Evidence in Toxic Substance Litigation: The Legacy of Agent Orange and Bendectin Litigation*, 86 NW. U. L. REV. 643, 644, 645 (1992). *See also Daubert*, 509 U.S. at 593.

[75] *See* POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 318 (emphasis added).

[76] *Id.*

[77] *Id*. (citing POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 37).

considered 'probable.'[78] "As always," Popper steadfastly maintains, "[all] science is conjecture."[79] He goes on to say, "[f]or us [falsificationists], therefore, science has nothing to do with the quest for certainty or probability or reliability."[80] Taken to its logical conclusion, Popperism would mean that a scientific statement proffered by a plaintiff cannot sustain a civil verdict, since science is based only on probable certainty and civil verdicts eschew decisions based on conjecture.[81]

We further learn that according to the view of Popper as embraced by the *Daubert* court, "the criterion of the scientific status of a theory is its falsifiability, or refutability, or testability."[82] Citing Popper's *Conjectures and Refutations: The Growth of Scientific Knowledge,*[83] the court tells us that:

> Scientific methodology today is based on generating hypotheses and testing them to see if they can be *falsified*; indeed, this methodology is what distinguishes science from other fields of human inquiry. . . . [T]he criterion of the scientific status of a theory is its falsifiability, or refutability, or testability.[84]

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[78] *See* POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 139 ("all theories are, and remain hypothesis: they are conjecture (*doxa*) as opposed to indubitable knowledge (*episteme*) . . . ."); *id* at 67 ("[Scientific] theories are passed on, not as dogmas, but rather with the challenge to discuss them and improve on them."); *id* at 235 ("[S]cience aims at *true* theories even though we can never be sure that any particular theory is true; and . . . science *may* progress . . . by inventing theories which compared to earlier ones may be described as better ***approximations*** to what is true.") (first emphasis in original; second emphasis added); *id.* at xi. ("The way in which knowledge progresses, and especially our scientific knowledge . . . is by guesses, by tentative solutions to our problems, by *conjecture.* These conjectures . . . can never be positively justified; they can be established neither certainly as true, nor even 'probable' . . . ."); POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 278 ("Science is not a system of certain, or well established, statements . . . Our science is not knowledge (*episteme*): it can never claim to have established truth, or even a substitute for it, such as probability.").

[79] KARL POPPER, POPPER SELECTIONS 126 (David Miller ed., Princeton Univ. Press 1985) (bringing down Popper's "The Problem of Demarcation," written in 1974).

[80] POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 310.

[81] *Model Civil Jury Charges*, NEW JERSEY COURTS, 1.12O, https://www.judiciary.state.nj.us/civil/charges/1.12O.pdf [https://perma.cc/6PFW-K9BM] ("Damages may not be based on conjecture or speculation.").

[82] Daubert v. Merrell Dow Pharms., Inc., 509 U.S. 579, 593 (1993) (quoting E. GREEN & C. NESSON, PROBLEMS, CASES, AND MATERIALS ON EVIDENCE 649 (1983) and POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 37).

[83] *Id.* at 593 (quoting KARL POPPER, CONJECTURES AND REFUTATIONS: THE GROWTH OF SCIENTIFIC KNOWLEDGE 44 (Routledge Classics 2002)). Popper's seminal work on the subject, *The Logic of Scientific Discovery*, was first published in German in 1934 before being translated to English in 1959. It was written 60 years before *Daubert* and thirty years before *Conjectures and Refutations*.

[84] *Daubert*, 509 U.S. at 593 (emphasis added) (quoting E. GREEN & C. NESSON,

An amicus brief from the American Association of the Advancement of Science concurs, noting: "Scientists conduct rigorous experimental testing in an attempt to *falsify* hypotheses."[85]

Popper constantly reiterates that 'falsifiability' is the *sine qua non* of science,[86] and that it is "not the *verifiability* but the *falsifiability* of a system [that] is to be taken as a criterion of demarcation" between science and non-science.[87] As one Popper apologist rhetorically asks, "[w]hat then do scientists do, if they don't [affirmatively] prove things?"[88] The commentator goes on to supply the 'proper' Popperian response:

> The most important action scientists take is to find errors. . . . "[S]cience is above all its method—essentially the critical method of searching for errors." . . . In the process, they filter error from theories and methodology, but they do not prove that the surviving methodologies—those that are left standing or those that are changed to correct errors—are valid.[89]

In a sentence, this commentator claims scientists *disprove* things.

Popper, however, requires both 'falsifiability'[90] and 'falsification'[91] By

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PROBLEMS, CASES, AND MATERIALS ON EVIDENCE 649 (1983) and POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 37).

[85] HAACK, *supra* note 73, at 137 (quoting Brief for the American Ass'n for the Advancement of Science et al. as Amici Curiae Supporting Respondent, *Daubert*, 509 U.S. 579 (No. 92-102), 1993 WL 13006281, *8-9.

[86] POPPER, POPPER SELECTIONS, *supra* note 79, at 11 ("[O]ur conjectures must further be restricted to those that are empirically falsifiable . . ." which is Popper's criterion of demarcation of empirical science from metaphysics (and pseudoscience)).

[87] KARL POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY 18 (Basic Books 1959) ("[E]mpirical science may be defined by means of its methodological rules. . . . [A] supreme rule is laid down . . . . It is the rule which says that other rules of scientific procedure must be designed in such a way that they do not protect any statement in science against falsification."). Later he contradicts himself: "In section 6, I tried to define empirical science with the help of the criterion of falsifiability; but . . . I was obliged to admit the justice of certain objections." *Id.* at 32.

[88] Beyea & Berger, *supra* note 20, at 337. One author is a physicist; the other is a lawyer.

[89] *Id.* (quoting David Miller, *Being an Absolute Skeptic*, 284 SCIENCE 1625 (1999)).

[90] *See* POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 65–66 ("A theory is to be called 'empirical or falsifiable' if it divides the class of all possible basic statements unambiguously into two non-empty subclasses. First, the class of all those basic statements with which it is inconsistent (or which it rules out or prohibits) . . . and secondly the class of those basic statements which it does not contradict (or which it permits.)"); *id*. at 70 (A theory is falsifiable if "it rules out, or prohibits, not merely one occurrence, but at least one event.").

[91] *See id.* at 66-67. Falsification requires the actual testing of the hypothesis. *See id*. at 18. Testing is a requirement he later withdraws. *See infra* notes 117 and 121; POPPER, POPPER SELECTIONS, *supra* note 79, at 12.

falsifiability, Popper means that the proposed precept is capable of being tested. If it is, Popper then asks, if it has been tested—i.e., *falsified*?[92] Popper's initial view (later modified and ultimately withdrawn) is that the two concepts are inseparable:[93] In the testing phase we are looking to *disprove* an assertion, not verify it.[94] Hypotheses that withstand falsifiability are presumed true until proven otherwise,[95] meaning we allow it to remain in our arsenal of 'scientific knowledge,' but only on a temporary basis, since, according to Popper, we 'know' all 'science' is capable of being disproved.

To restate Popper's view, he means that the proffered hypothesis is testable—*by showing it is wrong*. If, however, we believe that the hypothesis has not been proven wrong (no matter how many times we test it), Popper asserts that the information is regarded as true, but only temporarily—i.e, until proven otherwise. He means to tell us that all truths are temporary, and can only be provisionally relied on, until another test comes along and *falsifies* the prior results, which Popper expects as a matter of scientific course.

Thus, according to Popper, no scientific evidence can ever be considered 'reliable'[96] (a pre-requisite for legal admissibility)[97] because science is ever-changing.[98]

Here we see Popper's views on knowledge, (that "all knowledge is hypothetical" or "all knowledge remains . . . conjectural [and that] we never

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[92] *See generally* POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 20–21, 65–66, 72.

[93] About Fifty years later Popper backtracks. *See generally* KARL POPPER, REALISM AND THE AIMS OF SCIENCE: FROM THE POSTSCRIPTS TO THE LOGIC OF SCIENTIFIC DISCOVERY (1983). No one bothered to tell the Supreme Court that they were relying on 'outdated Popperisms.' *See also* POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY (1959), *supra* note 85, at 61 (acknowledging that there might be deficiencies and limitations in his proposal: "I admit that my criterion of falsifiability does not lead to unambiguous classification."); *infra* notes 115, 127.

[94] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 18 ("Theories, are therefore, *never* empirically verifiable.") (emphasis in original).

[95] POPPER, POPPER SELECTIONS, *supra* note 79, at 140.

[96] "'Reliable,' means 'consistently good in quality or performance; able to be trusted.'" Google Search, GOOGLE, https://www.google.com/search?q=Reliable&oq=Reliable&aqs=chrome..69i57j0l5.2512j0j4&sourceid=chrome&es_sm=91&ie=UTF-8 [https://perma.cc/N83N-24ML].

[97] *See* HAACK, *supra* note 73, at 108–09.

[98] Popper views scientific statements that cannot as yet be tested as 'pre-science' or what he calls 'metaphysical precepts' as pre-science. Should they be later shown wrong, (accidentally or otherwise), they now become falsified science. Thus they are either metaphysics or wrong science, depending on the time of viewing, "For the transition between metaphysics and science is not a sharp one: what was a metaphysical idea yesterday can become a testable scientific theory tomorrow . . . ." KARL POPPER, THE PROBLEMS OF DEMARCATION (1974), *in* POPPER SELECTIONS, *supra* note 79, at 123; *see also* POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 24.

know what we are talking about"),[99] leave an indelible paw-print on *Daubert*.

In sum, the Popperian view, as immortalized in *Daubert,* asserts that "an explanation or hypothesis that cannot be subject to the possibility of *rejection* . . . cannot be regarded as scientific."[100] This mantra is now well entrenched in case law. Professor Susan Haack demonstrates this by bringing down *Moore v. Ashland Chemical*,[101] noting that the *Daubert* court, relying on Green, says that "theoretically . . . hypotheses are not affirmatively proved, only falsified."[102]

B. Popping Popper

Many philosophers, both contemporaries of Popper[103] and modern ones,[104] reject Popper's views.[105] Paul Feyeraband, once a student of Popper, contends that "Popper's theory is a contribution to confirmation theory and has nothing to do with science."[106] Professor Haack, in her exhaustive treatment, demonstrates the flaws of *Daubert*'s reliance on Popper from a philosophical[107] or epistemological perspective, concluding that "to Popper, all scientific theories are in effect 'speculative hypotheses,'"[108] which therefore would be of little use to a jury and hence inadmissible. Other scholars, concurring,[109] have "objected to these passages [touting falsification] as philosophically naive, unhelpful, or out of date."[110]

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[99] Dykes*, supra* note 57.

[100] BJUR & RICHARDSON, *supra* note 25, at 79 (quoting F. Ayala and B. Black, *Science and the Courts*, 81 AMERICAN SCIENTIST 230, 236 (1993)).

[101] Moore v. Ashland Chem. Inc., 126 F.3d 679 (5th Cir. 1997).

[102] HAACK, *supra* note 73, at 144.

[103] Morris Cohen and Ernest Nagel criticized "falsification" as erroneous and asserted that scientific proof is based on inductive verifiability. COHEN & NAGEL, AN INTRODUCTION TO LOGIC AND SCIENTIFIC METHOD, *supra* note 68, at 383.

[104] Paul Feyerabend remarks that Logical Positivist Otto Neurath had already criticized Popper. Paul Feyerabend STANFORD ENCYCLOPEDIA OF PHILOSOPHY, *supra* note 1.

[105] Dykes, *supra* note 57 ("Tom Settle . . . stated firmly in 1970: 'As a criterion of demarcation between science and non-science, Popper's 'falsifiability'-plus-a-critical-policy does not work.' Other[s] agreed; among them A.J. Ayer, William C. Kneale, Imre Lakatos, Grover Maxwell, and Hilary Putnam.").

[106] Paul Feyerabend, *Dialogue on Method*, *in* THE STRUCTURE AND DEVELOPMENT OF SCIENCE 63, 95 (G. Radnitzky & G. Anderson eds., 1979).

[107] *See* KENNETH R. FOSTER & PETER W. HUBER, JUDGING SCIENCE: SCIENTIFIC KNOWLEDGE AND THE FEDERAL COURTS 42, 47, 48 (MIT Press 1997).

[108] HAACK, *supra* note 73, at 143. *See id*. at 140–55.

[109] Physicist and professor David Goodstein states: "I know of no example of a Nobel Prize awarded to a scientist for falsifying his or her own theory." David Goodstein, *How Science Works*, *in* REFERENCE MANUAL ON SCIENTIFIC EVIDENCE 37, 41 (Federal Judicial Center, 3d ed., 2011).

[110] D.H. Kaye, *On Falsification and Falsifiability: The First* Daubert *Factor and the Philosophy of Science,* 45 JURIMETRICS J. 473, 475 (2005). It appears judges are less than

Important scientists, even physicists[111] such as Max Planck who framed quantum theory, along with Claude Bernard, the father of the experimental method as used in physiology, also pointedly disagree with Popper.[112] Modern scientists concur—Professor Jon Butterworth, an experimental physicist involved with finding the Higgs Boson—talks about *proving* (not falsifying) its existence, not by a speculation, conjecture or theory, but as a virtual certainty, his words "beyond a reasonable doubt."[113] And when scientists who were instrumental in developing the scientific method of their respective fields contradict Popper[114]—it is time to realize the 'foundation is flawed' and the underpinnings of *Daubert* finally must be dismantled.

Only lawyers, it appears, are so blindly accepting—with perhaps the exception of Justice Rehnquist who gave a clear warning regarding the dangers of using falsifiability as the definer of 'science.'[115] In his *Daubert* dissent, Justice Rehnquist states: "I defer to no one in my confidence in federal judges; but I am at a loss to know what is meant when it is said that the scientific status

clear on the meaning of falsifiability. *Id*. at 476 n.13 (citing Sophia Godowsky et al., *Asking the Gatekeepers: A National Survey of Judges on Judging Expert Evidence in a Post-*Daubert *World,* 25 LAW & HUM. BEHAV. 433, 433 (2001)) (Prof Godowsky states: "In telephone interviews with written follow-up, only 5% of 400 state trial court judges gave answers that indicated a clear understanding of the notion.").

[111] Jon Butterworth, an eminent physicist and winner of the Chadwick prize alluded in a very negative fashion to those "who are just outraged at science's claims to some kind of objective truth and special status (the more mediocre philosophers or sociologists, mostly . . . .)" Could Butterworth perchance be referring to Popper, one wonders? JON BUTTERWORTH, SMASHING PHYSICS: INSIDE THE WORLD'S BIGGEST EXPERIMENT 212-13 (Headline Publishing Group 2014).

[112] *See* CLAUDE BERNARD, AN INTRODUCTION TO THE STUDY OF EXPERIMENTAL MEDICINE 18–19, 23–26, 33, 37, 44–47, 51 (Dover Publications 2014) (espousing induction, verification and scientific truths); *id.* at 52 ("The sceptic disbelieves in science and believes in himself; he believes enough in himself to dare deny science and to assert that it is not subject to definite fixed laws."). Bernard died before Popper was born and one would have sworn Bernard was castigating Popper's beliefs from his grave. Epidemiologists come out on both sides of the fence. *See generally* CAUSAL INFERENCE, (Kenneth Rothman ed. 1988); Carol Buck, *Popper's Philosophy for Epidemiologists*, 4 INT'L J. EPIDEMIOLOGY NO.3 159-168 (1975).

[113] BUTTERWORTH, SMASHING PHYSICS, *supra* note 111, at 271-272 (Headline Publishing Group 2014). Butterworth stresses that for experimental physicists doing cutting edge research the aim is *proving* a theory (not disproving or falsifying one). *Id.* at 97, 272. The general level of proof required in physics to proffer an opinion being three sigmas—i.e., a 99.7% degree of certainty. At five sigmas or 99.99994% degree of certainty (*id.* at 203), Butterworth asserts that scientists feel comfortable asserting that they have 'proved' a theory or made a discovery 'beyond a reasonable doubt' as was the case in the the "discovery" of the Higgs Boson." *Id*. at 219. *See also* Wolchover *supra,* note 59.

[114] *See* Wolchover *supra,* note 59199.

[115] Daubert v. Merrell Dow Pharms., Inc., 509 U.S. 579, 600 (1993) (Rehnquist, J., dissenting).

of a theory depends on its 'falsifiability,' and I suspect some of them will be, too."[116]

These objections have not infiltrated legal thinking, however, and we continue to find the oft-repeated sentiment that 'falsifiability' is the most important characteristic separating science from other forms of knowledge. In fact, Popper's falsifiability, attractive as it may be to many, has become so entrenched[117] that even stinging criticism from the scientific community has been unable to dislodge it.[118] Sheila Jasanoff, the Director of the Program of Science and Technology at Harvard University sharply attacked the otherwise well-received piece (at least within the legal community) of Francisco Ayala of the American Association for the Advancement of Science and Bert Black, an early and prolific *Daubert* commentator, for their mindless repetition of the *Daubert* mantra. Jasanoff states: "In their insistence on a unitary model of 'good' scientific practice and their unquestioning acceptance of 'testability' and 'falsifiability' Ayala and Black display almost complete disregard for findings in contemporary historical, political, and sociological studies of science."[119]

C. If You Can't Convince 'Em, Confuse 'Em

What confounds matters further is Popper's unfortunate choice of two similar terms to predicate his delineation of science vs. non-science, '*falsifiability'* (i.e., the capacity to test a theory and disprove it or the capability of a theorem to be so tested) and *falsification*[120] (the actual disproof of a scientific assertion, i.e., when a hypothesis is falsified).[121] Popper implicitly admits the possibility of confusion, noting that that it is important to "clearly distinguish between the terms."[122]

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[116] *Id*. Justice Rehnquist is focusing on the incomprehensibility of the concept. However, his view also respects the notion of judicial minimalism as enunciated by Cass Sunstein, i.e., "that judges should generally avoid broad rules and abstract theories and attempt to focus their attention only on what is necessary to resolve particular disputes." *See Originalism v. Minimalism* 9–11, CATO POLICY REPORT (Nov./Dec. 2014), http://www.cato.org/policy-report/novemberdecember-2014/originalism-v-minimalism [http://perma.cc/5ADY-J757].

[117] As electro-chemist George Gore noted in 1878, "attractive errors have a most tenacious existence." *See* GORE, *supra* note 18, at 86.

[118] *See generally* HANDBOOK OF SCIENCE AND TECHNOLOGY STUDIES (Sheila Jasanoff, et al. eds., 2001).

[119] SHEILA JASANOFF, SCIENCE AT THE BAR: LAW, SCIENCE AND TECHNOLOGY IN AMERICA 271–72 (Harvard Univ. Press 2009).

[120] KARL POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 65–66.

[121] About fifty years later Popper introduces a third term; further confusing matters, now distinguishing between falsifiable and falsifiability as well as falsification. The distinction is impossible to discern and it may well be a distinction without a difference. *See* KARL POPPER, REALISM AND THE AIMS OF SCIENCE, *supra* note 93, at xx–xxiii; *c.f. supra* note 91.

[122] "[F]alsification being a criterion for the empirical character of a system of statements." KARL POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 66.

In fact it is generally held in the law that "it is falsification, and not falsifiability, that matters,"[123] and that "*Daubert*'s parenthetical phrase, '*has been* tested,' is far more significant than the hypothetical, '*can be* tested.' The blurring of these matters in Justice Blackmun's opinion . . . has permitted obvious misapplications of the demand for testing."[124]

Popper, himself, however, never seems to have actually said this. In fact, he seems to state the contrary:[125] "I do not demand that every scientific statement must *have in fact been tested* before it is accepted. I only demand that every such statement must be *capable* of being tested."[126]

Hence, it is not clear whether the legal standard for defining science is "falsifiability" or actual attempts at "falsification." It must be recognized that Popper, himself, disdained definitions as unnecessary and confusing.[127] As Popper historian David Miller notes, "Popper forthrightly assails the undeservedly widespread dogma that definitions, and the precision fondly imagined to spring from them, are essential to any logical articulation of our thoughts, and even to plain clear thinking."[128] Popper, in fact, later unapologetically redefines his terms, giving falsifiable and falsifiability different meanings,[129] thereby further increasing the confusion.[130] Perhaps at the end of the day Popper would not have cared much whether the key

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[123] Kaye, *supra* note 110 at 478.

[124] *Id*. (quoting Daubert v. Merrell Dow Pharms., Inc., 509 U.S. 579, 593 (1993)); Daubert v. Merrell Dow Pharms., Inc., 509 U.S. 579, 593 (1993) ("Ordinarily, a key question to be answered in determining whether a theory or technique is scientific knowledge . . . will be whether it can be (and has been) tested.").

[125] KARL POPPER, REALISM AND THE AIM OF SCIENCE, *supra* note 93, at xix ("My proposal was that a statement (a theory, a conjecture) has the status of belonging to the empirical sciences if and only if it is falsifiable.").

[126] KARL POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 26. *But see id.* ("[I]n other words, I refuse to accept the view that there are statements in science which we have, resignedly, to accept as true merely because it does not seem possible, for logical reasons, to test them."); *see also supra* note 91 and accompanying text (taking a different position); *supra* notes 93, 121 and accompanying text (seeming to admit being very confused).

[127] Dykes, *supra* note 57, at 6 ("Definitions do not play any very important part in science . . . . Our 'scientific knowledge' . . . remains entirely unaffected if we eliminate all definitions."; "Definitions never give any factual knowledge about 'nature' or about the 'nature of things.'"); "Definitions . . . are never really needed, and rarely of any use.") (first quoting KARL POPPER, THE OPEN SOCIETY AND ITS ENEMIES 14 (2012); then quoting POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 20-21; and then quoting POPPER, REALISM AND THE AIM OF SCIENCE, *supra* note 93, at xxxvi).

[128] KARL POPPER, POPPER SELECTIONS, *supra* note 79, at 15.

[129] *See* KARL POPPER, REALISM AND THE AIM OF SCIENCE, *supra* note 93, at xxii (noting two conceptions for falsifiability—one being a "logical-technical" term and a different one signifying "demonstrable").

[130] As Popper says, "An entire literature rests on the failure to observe this distinction." *Id.*

criterion is falsification or merely falsifiability,[131] as long as we recognize the criticality of systematically attempted *disproof* as part of the scientific method.[132]

While recognizing that a falsified result which eliminates a theorem from our arsenal of scientific knowledge was bound to elicit confusion,[133] Popper's position on the import of falsification is sacrosanct: once a theory has been falsified, the approach should be entirely rejected without sentimental attachment to keeping the theory on life-support by *ad hoc* explanations.[134] Popper himself noted that "science proceeds on the assumption that contradictions are impermissible and avoidable, *so that the discovery of a contradiction forces the scientist to make every attempt to eliminate it; and indeed, once a contradiction is admitted, all science must collapse*."[135]

Sadly for Popper (and *Daubert*)—this approach does not work in many scientific pursuits, as we shall see, thereby rendering Popper's philosophy unsuitable for forensic use.

Eventually, after many years of backing and forthing, bobbing and weaving, giving and taking back on his bevy of 'false' definitions, even Popper comes to realize the infirmities of his position.[136] Towards the end of his life he stresses that "every empirical falsification . . . should not be taken too seriously."[137] His admission is not without a note of bitterness. After getting hopelessly befuddled trying to detangle his concept of *falsifiable* from *falsifiability* and *falsification*, Popper complains that none of these definitional issues would

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[131] Popper constantly proposes new definitions only to retract or qualify them—or confuse us—later. *See* POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 251.

[132] Nevertheless, Popper recognized there might be deficiencies and limitations in his proposal. *Id*. at 32 ("In section 6 I tried to define empirical science with the help of the criterion of falsifiability; but I was obliged to admit the justice ['justification' in 1959 ed.] of certain objections."). *See also* POPPER, REALISM AND THE AIM OF SCIENCE, *supra* note 93 and accompanying text.

[133] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY (1959), *supra* note 87, at 86.

[134] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY (2002), *supra* note 64, at 131 (referring to the "rule or principle which restrains us from indulgence in *ad hoc* hypotheses and auxiliary hypotheses"). *See also* POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 81.

[135] POPPER, OPEN SOCIETY AND ITS ENEMIES, *supra* note 127, at 253 (first emphasis in original; second emphasis added). In this book, first published in 1945, Popper produces an incomprehensible diatribe about German Philosopher Georg Hegel's views of contradictions and its relationship to science. Hegel's views in fact are far more akin to the way science actually works—at least biology, chemistry and Newtonian physics, than is Popper's. *But see* BUTTERWORTH, SMASHING PHYSICS, *supra* note 111, at 214 (citing with approval a quote from Isaac Asimov, the scientist and science writer, to wit: "It probably makes more sense to describe previously successful but now discarded theories as 'incomplete' rather than 'wrong.' . . . The new theory would be more complete, and in this sense more true.").

[136] POPPER, REALISM AND THE AIMS OF SCIENCE, *supra* note 88, at xxiii.

[137] *Id*.

make any difference,

> but for the fact that it has led some people to abandon rationalism in the theory of science, and to tumble into irrationalism. For if science does not advance rationally and critically, how can we hope that rational decisions will be made anywhere else? A flippant attack on a misunderstood logical-technical term has thus led some people to far-reaching and disastrous philosophical and even political conclusions."[138]

This postscript, however, never made its way to the legal case books and we are stuck with Popper's initial statements proffered by legal philosophers who offered him up to the Court as a pagan sacrifice to scientific truth.

III. BLACK HOLES IN THE ORIGIN OF POPPER'S UNIVERSE

A. Popper's Past as Prologue: Quantum Obsession and Skewed Motivation

Before demonstrating the inaptitude of Popper's philosophy to the quotidian science of the courtroom, it might be useful to consider its derivation: "Everybody knows that Popper's main formal background was in physics and mathematics. It so happens, however, that what everybody knows is false. In fact, Popper [was] an amateur physicist and mathematician, his formal training having been in education and in Gestalt psychology."[139] It is also commonly believed that Popper's aversion to questionable science is derived from his opposition to Freud and Adler's claim that psychotherapy is a *bona fide* science and from his objections to Marxism.[140] This is undoubtedly true,[141] but it is merely a manifestation of Popper's ever-changing mindset[142] throughout the 1920s,[143] which crystallized in the thirties into an uncompromising reaction to developments in modern physics.

In fact, Popper had no formal training in any of the natural sciences,

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[138] *Id*. *Cf. supra* notes 91, 123-126 132, and accompanying text.

[139] W.W. Bartley, III, *Theory of Language and Philosophy of Science as Instruments of Educational Reform: Wittgenstein and Popper as Austrian Schoolteachers*, *in* METHODOLOGICAL AND HISTORICAL ESSAYS IN THE NATURAL AND SOCIAL SCIENCES 319 (R. S. Cohen & M. W. Wartofsky eds., 1974) (noting Popper's psychological training was under the supervision of Karl Buhler).

[140] KARL POPPER, AN UNENDED QUEST: AN INTELLECTUAL AUTOBIOGRAPHY 35–39 (Routledge Classics 2002).

[141] POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 9.

[142] MALACHI HAIM HACOHEN, KARL POPPER – THE FORMATIVE YEARS, 1902-1945: POLITICS AND PHILOSOPHY IN INTERWAR VIENNA 168 (2001) (noting that Popper's autobiographical rendition of the timing of his discoveries must be radically revised).

[143] Bartley, *supra* note 139 (noting that Popper's formal training was in education and in Gestalt psychology); *see also* David Corson, *Critical Realism: Post Popper Realism for The Real World*, *in* IMPROVING EDUCATION: REALIST APPROACHES TO METHOD AND RESEARCH 67 (Joanna Swann & John Pratt eds., 1999).

including physics.[144] He says of his abilities in that area, "I felt in the end that I was not really good enough."[145] But the exciting discoveries of the new science, quantum mechanics, motivated him to educate himself,[146] especially as he began his stint as a high school physics teacher.[147] Popper explains: "At the time (1930) . . . I began writing my book, modern physics was in turmoil. . . . From the very beginning there was dissension and confusion. The two greatest physicists, Einstein and Bohr, perhaps the two greatest thinkers of the twentieth century, disagreed with one another."[148]

Somehow about this time Popper became embroiled in a debate about the work of Neils Bohr.[149] It appears that in1935, Albert Einstein, Boris Podolsky and Nathan Rosen of the Technion wrote an article discussing whether quantum mechanical descriptions can ever be considered complete, arguing in the negative.[150] Soon after its publication, the article was criticized by Bohr.[151] And here is where Popper jumped into the fray, claiming Bohr's views supported subjectivity in science and abandoned scientific realism, a notion that horrified him,[152] motivating him to insert himself in a dispute he refused to let go of.[153]

Popper's view, that "the most basic predictions of quantum mechanics should continue to be tested, with an eye towards falsification rather than mere adding of decimal places to confirmatory experiments"[154] drove him to

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[144] Bartley, *supra* note 139 (noting that Popper's formal training was in education and in Gestalt psychology); *see also* Corson, *supra* note 143, at 67 (noting that he did have training in philosophy and the history of music, however, and chose to take his oral doctoral exams in those subjects).

[145] Don Howard, *Popper and Bohr on Realism in Quantum Mechanics*, 1 QUANTA 33, 36 (2012).

[146] William M. Shields, *A Historical Survey of Sir Karl Popper's Contribution to Quantum Mechanics*, 1 QUANTA 1 (2012).

[147] Even his oral doctoral exams were in philosophy (including psychology) and the history of music! *See* HACOHEN, *supra* note 142, at 172.

[148] William M. Shields, *Karl Popper's Quantum Ghost*, Dep't of Science and Technology Studies, Virginia Tech, 2 (2004), http://www.tvsfpe.org/_images/popperquantum.pdf [https://perma.cc/VHF8-T4VC].

[149] *Id*. at 3 ("Popper lays out his criticism of what is commonly called the Copenhagen Interpretation of quantum theory–largely the work of Bohr–and the position of Heisenberg that the uncertainty relations must be viewed subjectively, as a 'limitation of our knowledge' of physical systems.").

[150] A. Einstein, B. Podolsky & N. Rosen, *Can Quantum Mechanical Description of Physical Reality Be Considered Complete?*, 47 PHYS. REV.. 777, 777 (1935).

[151] N. Bohr, *Can Quantum-Mechanical Description of Physical Reality be Considered Complete?*, 48 PHYS. REV. 696, 696 (1935).

[152] *See* POPPER, AN UNENDED QUEST, *supra* note,140, at 150.

[153] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 468 ("Bohr's reply seems unacceptable to me for at least three different reasons.").

[154] Shields, *supra* note 148, at 1.

propose his own experimental method. But Popper's experiment was a failure, trounced not only by Bohr but also by Einstein, who demonstrated that Popper's proof didn't prove (or disprove) anything.[155,156] At least having some integrity on this point, Popper conceded that his experiment "has been shown to be in principle impossible (from the quantum-theoretical point of view)."[157] Nevertheless, the public humiliation of his failed experiment had a deep impact. For the next fifty years Popper worked on reestablishing his credibility in the field of quantum mechanics, continually trying to refine an appropriate experiment, and in the process internalizing a fundamentalist-like reverence for quantum physics and its inherent uncertainties.[158] In so doing, he solidly entrenched his falsification ideas into philosophical thought.[159]

Popper himself notes the emotional impact which he says lasted until sometime in 1948 or 1949 (although a Popper historian, William Shields, claimed that it lasted much longer):[160] "I could not get over my mistaken thought experiment . . . I took this mistake very much to heart . . . I thought that my blunder proved my incompetence . . . . I felt defeated, and I was unable to resist the tremendous impact of Bohr's personality."[161]

Popper's antagonism to Bohr's viewpoint (if not to Bohr himself) bordered on the emotional and was likely triggered by Bohr's suggestion that "mere knowledge" of things had an observable physical effect.[162] "To Popper this was nearing something like belief in the paranormal."[163] Shields recounts that "Popper tells us in the opening pages of *Schism* that his 'strongest reason for my own opposition . . . lies in its claim to finality and completeness,'" thus the requirement to continued re-testing and that "Popper designed and promoted

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[155] The dispute came to a head at a scientific conference in Italy, per Shields, but Popper and Einstein were in correspondence for months thereafter, correspondence in which Einstein rejects Popper's proposed experiment. While Popper eventually resigns himself to this failure (at least for the time) conceding that "Einstein's letter 'briefly and decisively disposes of my imaginary experiment'," Popper takes issue with Einstein over determinism, and refuses to budge. William M. Shields, *supra* note 148, at 4.

[156] Regarding "the problem of subjective probabilities, and of drawing statistical conclusions from nescience [lack of knowledge or ignorance], [i]*n this, I still disagree with Einstein*." (emphasis added). KARL POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 481.

[157] *Id*. at 466 n.4.

[158] *See* Shields, *supra* note 148.

[159] Don C. Grant & Edwin Harari, *Psychoanalysis, Science and the Seductive Theory of Karl Popper*, 39 AUSTRALIA & NEW ZEALAND J. PSYCHIATRY 446, 446–52 (2005).

[160] "While he did not stop thinking about quantum mechanics, he 'remained for years greatly discouraged." Shields, *supra* note 148, at 4.

[161] POPPER, UNENDED QUEST, *supra* note 136, at 104 (admitting that he defended his thought experiment against Heisenberg and others, and he remained unconvinced until Einstein voiced his objections).

[162] Shields, *supra* note 148, at 14.

[163] *Id*.

'his experiment' not so much to prove quantum mechanics [Bohr's physics] wrong, as to restore the 'conjectures and refutations' attitude in quantum theory."[164]

Popper's relentless response may have been an over-reaction to a prevalent mindset of the day: mindless and uncritical acceptance of popular philosophies. Alternatively, it might have been a relic of his disenchantment with the Marxism he flirted with in his teens. It might have been further stoked by the unchecked spread of fascism. Or possibly it was the impending annexation of Austria by the German Reich, resulting in Popper's exile to New Zealand in 1937.[165] Or it might have been the compilation of all these forces that generated his dogmatic[166] anti-dogma-polemic against totalitarian thought, his insistence on continued testing and an obsessive need to attempt to falsify current knowledge.

At any rate, following this failed experiment, Popper began to persistently publicize his new philosophy of science.[167] Whether this was done as subterfuge to attack rigid dogmatic thinking of the social activists of the day, to deflect attention from his public failure of his mind-experiment, or to regain some stature in the scientific world we shall never know. (Although, it appears he never achieved the latter goal. Asher Peres, a student of Rosen (the co-author of the Einstein, Podolsky, Rosen paper which began the entire chain of events),[168] heavily criticized Popper's 'science', his knowledge of the history of quantum physics in general and his misuse of scientific terms.[169] Even Albert Einstein, Popper's 'icon', was categorically negative on the influence of philosophers on science, writing:

I am convinced that the philosophers have had a harmful effect on the

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[164] *Id*. at 14–15.

[165] POPPER, UNENDED QUEST, *supra* note 140, at 120-27.

[166] Popper acknowledges the value of a dogmatic attitude, especially when supporting one of his own maxims. Antonis A. Kousoulis, *What do you think on Karl Popper's view on the dogmatic scientist?*, RESEARCHGATE, (Oct. 8, 2015) http://www.researchgate.net/post/What_do_you_think_on_Karl_Poppers_view_on_the_dogmatic_scientist [https://perma.cc/PJT2-J6ZV] ("There is need for some dogmatism. The dogmatic scientist has an important role to play. If we give into criticism too easily, we shall never find out where the real power of our theories lies"). *See also* KARL POPPER, THE OPEN SOCIETY AND ITS ENEMIES, 374 (Princeton University Press, 1950); POPPER , CONJECTURES AND REFUTATIONS, *supra* note 62, at 420.

[167] *See generally* Shields, *supra* note 148.

[168] ASHER PERES, QUANTUM THEORY: CONCEPTS AND METHODS (Alwyn V. D. Merwe ed., 2002).

[169] Asher Peres, *Karl Popper and the Copenhagen Interpretation* 1, 3, 4 (1999), http://arxiv.org/pdf/quant-ph/9910078.pdf [https://perma.cc/GA5H-4MBR] (Peres states that "[t]he absurdity of Popper's result only confirms Bohr's approach."). Asher Peres was a student of Einstein's co-author, Rosen. *See Asher Peres' Obituary*, http://tx.technion.ac.il/~peres/ [https://perma.cc/R3XN-48B5]. The obituary includes Asher Peres' eulogy for Nathan Rosen.

> progress of scientific thinking in removing certain fundamental concepts from the domain of empiricism, where they are under our control, to the intangible heights of *a priori*. For even if . . . the universe of ideas cannot be deduced from experience by logical means, but [it] is in a sense, a creation of the human mind, without which no science is possible . . . .[170]

Nevertheless, no doubt as a consequence of Popper's persistent writings, the philosophy of falsifiability became solidly embedded as the delineation of "the scientific" and earned Popper the appellation of one of the greatest philosophers of the twentieth century.[171]

Over the next decades Popper eventually came to believe that Bohr's concept of "understanding" was different from his own, and much narrower.[172] Bohr's thought processes, Popper concluded, were based on visual models of picture and models; his own being an understanding of the logical force of a theory, its explanatory power, its relation to other relevant problems and other theories.[173] It is no wonder that Popper came to oppose the empirical nature of science and concentrated on its logic, for that was the area in which he felt he bested Bohr.[174] But Popper's unrepentant stance in opposing Bohr and his disputes with Einstein[175] over determinism, (causation) and probability[176] should have exposed Popper's true colors. In Popper's obstinate opposition to their positions, he contradicts his own views of science, which is that 'the craving to be right'—is wrong.[177]

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[170] ALBERT EINSTEIN, THE MEANING OF RELATIVITY 3 (1956). While it might seem that Einstein is in error in his use of "deduced," he may have well been directly referring to Popper, who viewed all 'true' science as being deductive in origin. Thus, Einstein may have been subtly attacking this notion by saying that not everything in the Universe of science can be 'deduced.'

[171] Stephen Thornton, *Karl Popper*, THE STANFORD ENCYCLOPEDIA OF PHILOSOPHY, *supra* note 1, at 5.

[172] POPPER, UNENDED QUEST, *supra* note 140, at 105.

[173] *Id.*

[174] Novakovic states that "Accordingly, critical thinking is, for Popper the main instrument in the attempt to refute any scientific theory. 'Observations are used,' these are Popper's words, only if they fit into our critical discussion." Stanisa Novakovic, *Is the Transition from an Old Theory to a New One of a Sudden and Unexpected Character?, in* METHODOLOGICAL AND HISTORICAL ESSAYS IN THE NATURAL AND SOCIAL SCIENCES 174 (Robert S. Cohen & Marx W. Wartofsky eds. 1974).

[175] POPPER, UNENDED QUEST, *supra* note 140, at 150–51.

[176] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 481 ("[T]he problem of subjective probabilities, and of drawing statistical conclusions from nescience. In this I still disagree with Einstein.").

[177] "The wrong view of science betrays itself in the craving to be right; for it is not his possession of knowledge, or irrefutable truth that makes the man of science, but his persistent and recklessly critical *quest* for truth." POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY (1959), *supra* note 85, at 281.

B. To Popper, All Science Is Physics

It turns out that Popper's overall view of science is rather amorphous and hardly as pristine or exact as we would expect. Thus, he says: "what is to be called a 'science' and who is to be called a 'scientist' must always remain a matter of convention or decision."[178] At one point he lumps biological phenomena with sociological phenomena.[179] Nevertheless, he unabashedly tells us that to him, "all science is cosmology."[180, 181] His focus on falsifiability—the only method available to try to validate hypotheses in cosmology and quantum physics, (as space, time and the beginnings of the universe do not readily lend themselves to a test-tube or laboratory experiment), would logically derive from his obsession with the field. In fact Popper admits that in "modern theoretical physics, I and others see the most complete realization to date of what I call 'empirical science.'"[182] Popper was not alone in this belief; it was a conviction he may have gleaned from Ernest Rutherford, who won the Nobel Prize for physics in 1908[183] and to whom the aphorism "all science is either physics or stamp collecting" is attributed.[184]

Popper's chauvinistic views of physics, however, have strong opponents in the scientific community. J.D. Bernal says quantum physics is "a world of its own."[185] As far back as 1878, George Gore, the chemist who worked with phosphorus and invented matches, noted that biology was far more complex than classical physics or chemistry.[186] Modern day theorists such as Richard

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[178] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 31.

[179] In regard to the biological or sociological phenomenon he looks at science as a "tool, or an instrument, comparable perhaps to some of our industrial machinery." *Id.* at 81.

[180] POPPER, POPPER SELECTIONS, *supra* note 79, at 25; *see also* POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at xviii. It must be noted that Popper's view of "empirical science" would shock most readers. He eschews knowledge via observation, arguing that only logic and reason provide the "empirical evidence" we need. POPPER, POPPER SELECTIONS, *supra* note 79, at 25, 27, 30.

[181] According to NASA, cosmology refers to "the scientific study of the large scale properties of the universe as a whole," in other words "the Big Bang." *Cosmology: The Study of the Universe*, NAT'L AERONAUTICS AND SPACE ADMIN., http://map.gsfc.nasa.gov/universe/ [http:// perma.cc/7BTF-9VV3].

[182] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 15.

[183] *Ernest Rutherford*, RANDOM HOUSE WEBSTER'S DICTIONARY OF SCIENTISTS 417 (1997)

[184] *See also* P.M.S. Blackett, *Memories of Rutherford, in* RUTHERFORD AT MANCHESTER 108 (J.B. Birks ed., 1962) (although noting that some attribute the quote to Lord Kelvin).

[185] J.D. Bernal thought that physics is an unusual science, being the combination of experiment and self-contained theory. ("There is undoubtedly a view now that the experiment is really a kind of unfair physics and that if we only thought hard enough we would have all the answers without bothering to experiment."). *See* BERNAL, *supra* note 62, at 302.

[186] GORE, *supra* note 18, at 143,146.

Lewontin and Nancy Cartwright agree,[187] holding that at the very least, the biological sciences are inherently different from physics.[188]

> Traditionally, philosophers of science have focused on physical laws, which were taken to be at least true, universal statements that support counterfactual claims. But, although this claim about laws might be true with respect to physics, laws in the special sciences (such as biology, psychology, economics etc.) appear to have—maybe not surprisingly—different features than the laws of physics.[189]

In fact, "Nancy Cartwright has said that the laws of physics lie."[190] While perhaps others may not make such extreme claims, it is generally accepted that biology—and the way it is practiced—takes a very different approach than physics:

> With the success especially of the biological sciences it became clear that there is genuine scientific knowledge that does not conform to the paradigm of physics. As a consequence, scientific practice in the special sciences was no longer taken to be deficient but was analyzed as a legitimate practice different from physics.[191]

Thus, while Popper's system of falsification and falsifiability is embraced by most modern day physicists (at least theoretical ones; modern experimental physicists appear to differ, embracing the notion of positive proof),[192] and may well be suitable to a field where controlled experiments are impossible, Popper rigidly applies this system across the boards of the sciences, even though it is inapplicable to the biology, chemistry, or Newtonian physics of the court docket.[193]

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[187] *See* Carl Hoefer, *Introducing Nancy Cartwright's Philosophy of Science, in* ROUTLEDGE, NANCY CARTWRIGHT'S PHILOSOPHY OF SCIENCE 1–2 (Stephen Hartmann et al., eds., 2008).

[188] Nancy Cartwright, *Why Physics?, in* ROGER PENROSE ET AL., THE LARGE, THE SMALL AND THE HUMAN MIND 166 (Malcolm Longair ed., 1997). Nancy Cartwright noted: "Essentially all sciences except physics are special sciences. That means that their laws hold at best only *ceteris paribus*," meaning they "hold only so long as nothing from outside the domain of the theory in question interferes." Thus biology and chemistry requires a greater degree of flexibility in assessment than evidence from physics, which is believed to be a closed system. *Id*.

[189] Ceteris Paribus Laws, STANFORD ENCYCLOPEDIA OF PHILOSOPHY, *supra* note 1 (*Ceteris paribus* comes from the Latin all "other things being equal.").

[190] William Wimsatt, *Lewontin's Evidence (That There Isn't Any*), *in* QUESTIONS OF EVIDENCE: PROOF, PRACTICE AND PERSUASION ACROSS THE DISCIPLINES 492, 492 (James Chandler et al. eds., 1994).

[191] Ceteris Paribus Laws, *supra* note 189.

[192] QUESTIONS OF EVIDENCE: PROOF, PRACTICE AND PERSUASION ACROSS THE DISCIPLINES 7, 478–91, 504–09 (James Chandler et al. eds., 1994). *See also* BUTTERWORTH, *supra* note 111.

[193] SUSAN HAACK, DEFENDING SCIENCE - WITHIN REASON: BETWEEN SCIENTISM AND

With this background in mind, we proceed to deal with the fact that falsification has infiltrated the law and has survived attacks by philosophers, lawyers and logicians. To finally slay the *Daubert* dragon, we therefore look to science, proposing to show by scientific examples that 'Popper just doesn't pop.' In this case, we must re-craft judicial understanding of the meaning of science, good science and the scientific method in light of relevant forensic science: biology, chemistry and Newtonian physics. What I propose to do is to topple Popper by falsifying falsification, thereby hoisting Popper on his own petard.

William Harvey on the Circulation of Blood c. 1628 (courtesy Wikipedia)

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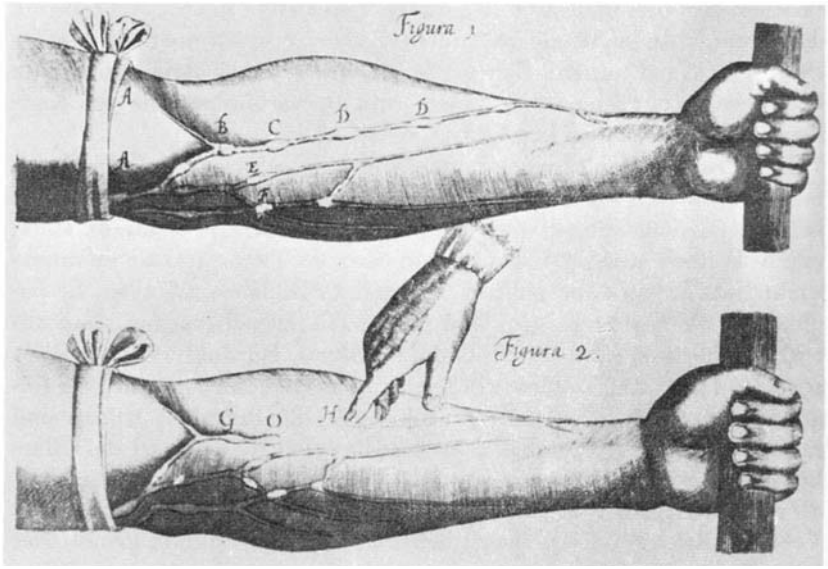

CYNICISM 251 (2003) (criticizing the "court's preoccupation with specifying what the method of inquiry is that distinguishes the scientific and reliable from the non-scientific and unreliable" because "[t]here is no such method"). *See* Haack, *supra* note 11, at 59; *see also* Susan Haack, *An Epistemologist in the Bramble-Bush: At the Supreme Court with Mr. Joiner*, 26 J. HEALTH POL. POL'Y & L. 217, 232 (2001) (contending that neither Hempel's nor Popper's philosophy of science can "help a judge decide either whether evidence proferred is really scientific, or how reliable it is"). *Cf.* Michael A. Mason, Comment, *The Scientific Evidence Problem: A Philosophical Approach*, 33 ARIZ. ST. L.J. 887, 902 (2001) (arguing that "Popperian uncertainty is not necessarily the appropriate view for courts to take in determining the admissibility of scientific evidence.").

C. Who Sold Out Bacon? A Prelude

As noted earlier, there were great thinkers whose views were at odds with Popper's. Among these were Francis Bacon (1561-1626), who was trained as a lawyer and ultimately became Attorney General and Lord Chancellor of England.[194] Bacon's prodigious accomplishments included formulation of the scientific method.[195] Out of Bacon's vision and insistence on testing and empirical verification came William Harvey's map of the circulation of the human blood system in 1628 (done around the same time as Galileo's work).[196]

To introduce the inapplicability of Popper's formulations to biology, we start by examining William Harvey's work and find that some of Harvey's discoveries are not falsifiable, for if we allow for the possibility of a humanoid whose arteries are carrying oxygenated blood *to the heart* instead of *away* from it—and, per Popper, we cannot rule this out—we find we are dealing with either a defective human (who cannot live) or a non-humanoid. In other words, the knowledge that human arteries carry oxygenated (bright red) blood away from the heart is a final and unchanging 'truth' and Harvey's finding cannot be falsified without torpedoing our entire notion of human biology.[197] Of course, Popper eventually realizes that this 'truism' wreaks havoc with his entire paradigm.[198] To deal with this breach in his philosophy, Popper creates a new class of propositions. Statements that cannot abide his rigid falsification system become 'extra-scientific.'[199] Popper must create several classes of 'extra-scientific' knowledge to deal with these 'truisms,' torturing his formulation of falsifiability to the extreme.[200]

By 1963 it appears Popper feels he needs an even stronger out than the extra-scientific definitional classes. Now he defends himself by noting that

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[194] BRYAN MAGEE, THE STORY OF PHILOSOPHY 74 (Neal Lockley et al. eds., 1998).

[195] *Id.* at 75–76. *See also* STEPHEN LAW, THE GREAT PHILOSOPHERS 57 (Quercus 2007).

[196] Laszlo Kosolosky & Dagmar Provijn, *William Harvey's Bloody Motion: Creativity in Science*, PSA 2012 CONTRIBUTED PAPERS, http://philsci-archive.pitt.edu/9414/1/Paper_Harvey's_bloody_motion_(submission_PSA).pdf [http://perma.cc/2X2X-XX3U] (an analysis of how Harvey reached his conclusions, involving observation, experiment, analogy and inference).

[197] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 251 ("From a methodological point of view, the possibility of falsifying a corroborated law is by no means without significance.").

[198] *Id*. at 251.

[199] "Popper called speculation that did not yield testable predictions "metaphysics." Wolchover, *supra* note 59.

[200] Amongst these classes of 'extra-scientific endeavor" are "strictly existential statements," (also called non-empirical since they are not falsifiable), "axioms", "equations" and "definitions." These fall into the pit of metaphysics. *See* POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 48–50, 52-54. As Prof. Daniel Ternos says, "Reading what Popper made out of his proposed test shows that he, actually, ignored his own precepts of what is science when discoursing about quantum foundations!" (personal communication, on file with author.).

"most dissectors of the heart before Harvey observed the wrong things—those, which they expected to see."[201] It appears Popper is justifying the need to continue trying to falsify Harvey's discovery long after it was conclusively proven just because others erred before him.

Knowing when an observation is completely safe or conclusively proven may well be unknown. It may be after thousands of repeated necropsies have yielded the same results, or millions of doctors over time and throughout the world see only red-blooded humans, or it may take the development of new instruments, such as fMRIs and cardiac catheterization to map blood flow (much as it took the telescope to prove Copernicus right). Even after new technology emerges, different standards or different manufacturing techniques might prevent reproducible findings, as happened to Anton Von Leeuwenhoek, whose microscope lenses were so superior to his contemporaries' that his findings could not be replicated for years after his death.[202] Nevertheless, it is one thing to say it may take decades or centuries to fully verify an idea, and another to say "[t]here can *never* be anything like a completely safe observation, free from the dangers of misinterpretation,"[203] or that "valid induction is not even metaphysical: it simply does not exist."[204]

We certainly know of scientific truths that cannot withstand falsification—i.e., they will *always* be true (the Earth is round; it rotates around the sun; gravity keeps us from falling off the planet, etc.). Even these eternal 'scientific truths,' however, cannot convince Popper's supporters of the flaws in his approach. We also recognize certain scientific 'truths' have been falsified.[205] Yet we cling, at least in law, like blind men to a lamp-post, to Popper, without regard to how truly effective it is. Thus to fashion an effective disproof of Popper, we begin systematically, first determining whether the notion of 'falsifiability' can, itself, be falsified.

D. Popper and Biology: Once Upon a Popper There Were (Only) White Swans:

Let us begin our formal effort to falsify Popper's scheme by evaluating one of his few concrete examples.[206] He starts by examining the hypothesis that

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[201] POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 55 n.8.

[202] WILLIAM BULLOCH, THE HISTORY OF BACTERIOLOGY, 29 (Oxford University Press 1938).

[203] POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 55.

[204] *Id*. at 70. For someone who eschews dogma, it is interesting to catch Popper in the act of the dogmatic.

[205] Although we are not sure how it happens, Mendel's genetics have been falsified in findings of brown-eyed children with blue-eyed parents. Barry Starr, *How Blue Eyed Parents Can Have Brown Eyed Children*, STANFORD AT THE TECH MUSEUM OF INNOVATION, http://genetics.thetech.org/how-blue-eyed-parents-can-have-brown-eyed-children [http://perma.cc/278L-NNKC].

[206] POPPER, POPPER SELECTIONS, *supra* note 79, at 15.

"all swans are white."[207] Popper says this statement cannot be *verified* because "induction is logically invalid [and therefore] no matter how many instances of white swans we may have observed, this does not justify the conclusion that *all* swans are white."[208] In other words, it is logically possible to *falsify* it[209] by observing a single black swan, so the statement cannot be 'true.'[210]

Popper's proposed hypothesis ('all swans are white') is merely a straw-man statement masquerading as a hypothesis. This is one example of Popper confusing epistemology with science, which would not accept his proposition as a valid hypothesis *ab initio*.[211] Any conclusions he makes of the truth, or the lack thereof, about the statement, do not, *ipse dixit,* apply to scientific propositions as raised in the practice of science.

Saint Hugh of Lincoln with his swan (Left) Altarpiece from the Charterhouse of Saint-Honoré, Thuison, France (ca. 1490-1500;) A Swan-Goose (below) (courtesy Wikipedia).

The problems with Popper's swan example from a scientific perspective are manifold. First, a scientist would not offer the statement "all swans are white" as a hypothesis (or fact) because (a) the statement is not derived from a systematized classification system with recognized criteria and evolutionary rationale; (b) nor is it a conclusion (logical inference) derived from a (controlled) and replicated experiment; and (c) there is no *biological* basis for

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[207] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 82-83; *id* at 66-67 (adding Ravens as an example).

[208] POPPER, POPPER SELECTIONS, *supra* note 79, at 110.

[209] *Id*. The term *falsifiability* is sometimes synonymous to *testability,* albeit only in a negative sense since Popper eschews the use of 'verifiability' which might be considered positive testing.

[210] *But see* BERNARD, *supra* note 112, at 37 ("We must trust our observations or our theories only after experimental verification . . . ."); *id*. at 33 ("Another essential of any hypothesis is that it must be as probable as may be and must be experimentally verifiable.").

[211] Popper backtracks saying that the hypothesis can be salvaged by being reformulated to include at least some potential falsifiers (i.e. conditions), the form any competent scientist would have used to begin with. As an *altered* hypothesis, he now says that the statement is 'falsifiable.' POPPER, REALISM AND THE AIM OF SCIENCE, *supra* note 93, at xx–xxiii.

the assertion.[212] In fact, "all swans are white" is nothing more than an opinion of which only a four-year-old could be proud, since no scientist would presume to contend s/he has evaluated every swan in existence.

Popper has more problems, however. His falsifiability/falsification framework is plain and provably wrong. Popper—at least according to his methodology—requires that we disprove (falsify) him only once to disprove his entire conceptual framework, which I will proceed to do.

Assuming, *arguendo*, a 'real' scientist had only observed white swans,[213] the scientist might say "all birds that have long necks, etc. and are white are called 'swans.'" The scientist would leave open the possibility that we might find something that otherwise looked like a swan but was black, in which case it might be called a 'blawn' without disrupting the classification scheme.

Should further investigation yield varieties of different coloration, such as 'swan geese,' thereby 'falsifying' the initial premise, the biologist, simply invents a new sub-species to demonstrate the scientific advance. Popperians, and perhaps quantum physicists, however, would void the classification scheme and opt for a new one. As Popper states: "We decide that if our system is threatened we will *never* save it by any kind of conventionalist stratagem."[214]

By 1974, Popper realized there was a simple, practical solution to the white swan/black swan dichotomy, i.e., furnishing a new name for the new entity, the conventionalist stratagem, which is, indeed, workable. Popper, however, does not like this approach: Yes, he says, the biologist can escape the refutation by creating a new *species* in the classification system (in Popper's unschooled biology, he says "the black swans would be considered a new 'kind' of bird"), but Popper dogmatically tells us, "I think that he is likely to learn more if he admits that he was wrong." [215] (!)[216]

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[212] As George Gore said in 1878: "No proposition can be proved to be true by means of experience alone, because experience is finite." GORE, *supra* note 18, at 88. Thus, no scientist would propose a hypothesis such as "all swans are white" which can only be 'true' based on the proponent's limited experience.

[213] The physicist Daniel Terno recounts a story about the quantum physicist and philosopher Abner Shimony regarding a philosophy graduate who wanted to do a PhD in philosophy of physics. Shimony "suggested that the student first had to do a degree in physics, and then he might be able to study its phylosphy [sic]" (personal communication, on file with author).

[214] POPPER, LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 67 ("If accepted basic statements [explained as an 'occurrence' or 'event'] contradict a theory, then we take them as providing sufficient grounds for its falsification only if they corroborate a falsifying hypothesis at the same time."). Popper says: "the class of . . . potential falsifiers is identical with that of all possible basic statements [occurrences or events]: it is falsified by any statement whatsoever." *Id*. at 71–72. *See also id.* at 61; Richard Boyd et al., The Philosophy of Science 108 (1934).

[215] POPPER, POPPER SELECTIONS, *supra* note 79, at 125.

[216] Too bad Popper doesn't take his own advice. When the water experiment comes up

Let us revisit the circulatory system in light of the white swan experiment. Would Popper venture that the statement 'all human (mammalian) blood is red' is not scientific because it is not falsifiable? According to Popperians, we must consider this as a real possibility, and we must be prepared to be able to falsify it, and if so falsified, reject its truth forthwith. He believes that "scientists . . . should make bold, highly falsifiable conjectures . . . and, should they be falsified when they are tested, drop them and start again rather than making *ad hoc* adjustments to save them."[217]

The scientist who did much work on the role of hemoglobin, the iron-containing molecule that transports oxygenated blood, Claude Bernard,[218] would not have agreed with Popper.[219] Bernard's version of falsifiability, posed about seventy years before Popper's, is remarkably similar to Popper's and hence far more original.[220] Nevertheless, Bernard's views are different in several respects. First, Bernard did not eschew induction as a means of pursuing scientific discovery, believing that experimental science is a constant interchange between induction and deduction. In addition, Bernard validated 'verification' as a conceptual mode of discovery. Most importantly, Bernard ratified the notion of cause and effect, about which he says, the scientist tries to determine the relation of cause and effect, "for there can be no effect without a cause. Determinism thus becomes the foundation of all scientific progress and criticism,"[221] a concept Popper strongly rejects. Bernard also vehemently eschewed falsification, stating: "[n]egative facts, no matter how numerous they may be, can never destroy a single positive fact. That is why pure and simple negation is not criticism, and this method should be absolutely rejected in science, because science is never built up by negation."[222]

This acknowledgement of the connection between cause and effect allows Bernard to succeed where Popper fails. For in searching for causes, we are forced to consider the *mechanism* of causation, and it is Popper's refusal to

(*see infra* notes 304-323), Popper recommends changing the name instead of admitting he was wrong!

[217] HAACK, *supra* note 73, at 128. *See supra* note 136 and accompanying text. However, Popper makes a curious statement in *Logic of Scientific Discovery* where he refers to a particular hypothesis as being "less testable than special relativity, it may illustrate a degree of *adhocness*" —whatever that means. POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 62 n.1.

[218] Vincent Geenen, *Claude Bernard (1813-1878), The Father of Modern Physiology and Experimental Medicine*, UNIV. OF LIEGE CTR. OF IMMUNOLOGY, INST. OF PATHOLOGY CHU-B23 at 4, http://orbi.ulg.ac.be//bitstream/2268/79049/1/C.BERNARD%20Text.pdf [https://perma.cc/8M5N-ZEYS].

[219] CLAUDE BERNARD, *supra* note 112, at 37 ("Truths once established are immutable.").

[220] *Id*. at 33 ("The experimental hypothesis, in short, must always be based on prior observation. Another essential element of any hypothesis is that it must be as probable as may be and must be experimentally verifiable."). *See also id*. at 53.

[221] *Id.* at 69; *see also id*. at 87, 178–79.

[222] *Id*. at 177.

consider causal mechanisms that denies him the option of making reliable future predictions. Thus, Popper contends that we cannot predict the sun will rise tomorrow based on our past experience.[223] However, it is not past experience that enables future 'scientific' predictions, but our understanding of the mechanisms responsible for these events. Because he is not concerned with mechanics of causation, (he does not believe in determinism[224] or cause and effect),[225] Popper can claim it is impossible to prove the sun will rise tomorrow, because we cannot predict future events from past ones.[226] Indeed, we can easily furnish examples that seem to support Popper's claim such as Malthusians population dynamics,[227] which predicted that there would be too many people for the world to feed by the year 2000,[228] or Paul Ehrlich's fifty year old predictions of the environmental apocalypse made in the 1960s,[229] forecasting similar doom from lack of resources. In fact, our experience has proven these predictions to be quite wrong. However, these predictions are

[223] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 251: ("[T]he 'principle of the uniformity of nature' can again be regarded as a metaphysical interpretation of a methodological rule—like its near relative, the 'law of causality.").

[224] "I have not changed my mind on this point, nor on the main points of my criticism. But I have changed my interpretation of quantum theory together with my interpretation of probability theory. My present views are to be found in my Postscript where I argue, independently of the quantum theory, in favour of indeterminism. Yet with the exception of section 77 (which is based upon a mistake) I still regard the present chapter as important—especially section 76." POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 211.

[225] "I shall, therefore, neither adopt nor reject 'the principle of causality'; I shall be content to simply exclude it, as 'metaphysical' from the sphere of science." POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 39; *id*. at 245 ("The belief in causality is metaphysical.").

[226] "Theories about the past rarely employ the exclusively predictive methods of testing required by Popper's falsifiability criterion." Stephen C. Meyer, *The Demarcation of Science and Religion*, *in* The History of Science and Religion in the Western Tradition (Gary Ferngren, ed., 2000), *available at* http://www.discovery.org/a/3524 [https://perma.cc/L8TD-6KSK]. Karl Popper, § 7, Stanford Encyclopedia of Philosophy, *supra* note 1; *see* also POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 11 ("Before a theory has been refuted we can never know in what way it may have to be modified. That the sun will always rise and set within twenty-four hours is still proverbial as a law 'established by induction beyond reasonable doubt'").

[227] THOMAS MALTHUS, AN ESSAY ON THE PRINCIPLE OF POPULATION (Elec. Scholarly Publ'g Project 1998). *Cf.* STEPHEN G. BRUSH, MAKING 20TH CENTURY SCIENCE: HOW THEORIES BECAME KNOWLEDGE 80 (Oxford Univ. Press 2015) ("Malthusian theories about the effects of population increase on resources and the standard of living do fit this description . . . such theories continue to be to be supported by scientists even though . . . all of their specific novel predictions have turned out to be wrong.").

[228] *Id.*

[229] *See generally* PAUL R. EHRLICH & ANNE H. EHRLICH, POPULATION, RESOURCES, ENVIRONMENT: ISSUES IN HUMAN ECOLOGY 235–45 (W.H. Freeman 1970) (arguing the importance of population control).

based on past experience and extrapolation, and not on valid scientific principles. And indeed, past experience alone cannot predict future events.

But, if the predictions were based on an understanding of causal mechanisms, then predictions are indeed possible, and in fact such are the goals of modern science. Thus, where we do know the mechanism responsible for causing the event in question: we will see the sun rise tomorrow because the earth rotates around the sun, we most certainly can predict that this event will happen tomorrow, for if it does not, the only explanation would be that either there is no more sun, or that the Earth has stopped rotating. Should either of these eventualities occur, human life will also cease to exist—and none of this will matter.

Popper's refusal to respect the *'why'* of science, (i.e., the mechanics of scientific discovery and causal connections) enables him to build thought-castles in the sky where he ensconces his mythical principality of science, to which *Daubert* remains tethered. As causation (and hence causal mechanisms) is rejected from Popper's consideration[230] one wonders how his approach can establish the scientific considerations in negligence and products liability law under *Daubert*—when an essential element of these claims is proof of causation.

Let us now return to investigating *why* human blood color (i.e. all human blood is red) differs from Popper's swan colors (i.e., all swans are white). If we believe that color is a whimsical decision by the Chief Artisan of the Universe, then Popper is correct—we may well find a turquoise swan, for what difference does it make to the swan's existence? Similarly, if Creator-color-preference were involved, we could entertain the notion of finding a green-blooded human and falsifying our initial premise—that 'all human blood is red'—because it does not matter to the existence of the human from a physiological or evolutionary biological perspective. However, where color has a scientific significance or biological importance, such as the plume color of a peacock, statements regarding its fungibility cannot be so easily jettisoned.

Scientific knowledge teaches that the color of human (or mammalian) red blood cells derives from the iron-containing, heme-mediated functionality of hemoglobin (i.e., its oxygen-carrying capacity);[231] the red color comes from iron in the hemoglobin.[232] Should we find a humanoid with, let's say, green blood, we would conclude (from our knowledge of chemistry) that that entity's oxygen-carrying physiology is not mediated by iron (i.e., that person would not

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[230] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 245 ("The *metaphysical belief* in causality seems thus more fertile in its various manifestations than any indeterminist metaphysics of the kind advocated by Heisenberg."). *See also* POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 84.

[231] STANLEY W. JACOB ET AL., STRUCTURE AND FUNCTION IN MAN 336 (1978).

[232] Billauer, *supra* note 12, at 57 (citing Lexington Mill & Elevator Co. v. United States, 202 F. 615 (8th Cir. 1913), *aff'd* United States v. Lexington Mill & Elevator Co., 232 U.S. 399 (1914)).

be human). Alternatively, we could conclude that the humanoid has a particular medical problem. Rather than regarding our finding of a green-blooded human as a falsification of our initial premise, as Popper would have us do, this finding should propel further investigation into the cause of our 'aberrant' green-blooded humanoid (if not, her physician likely would be held liable for malpractice).[233]

Since we accept the immutability of the non-falsifiable statement that "all human blood is red except for those who are diseased," we first investigate whether disease is involved in our green-blooded specimen, in which case we may find a medical cause, for example, the unusual green color may arise from an excessive dose of a particular drug.[234] Should we fail to find a medical explanation, we must determine that green-blooded humanoid is not really human. Let us call him 'Vulcan'. Since we know that human blood is red due to the iron color of the oxygen-mediating component of human blood, we are now able to *validly* hypothesize *why* the Vulcan's blood is green. Indeed, further investigation reveals that the Vulcan's creator (Gene Roddenberry) chose Mr. Spock's blood color, not because of Roddenberry's *verdi-philic* aesthetics, but because the physiological determinant of Vulcan blood color is the copper, which renders blood color as green.[235] Thus, along with focusing on the question of "why," *it is the negation of falsification that allows us to propel our research forward in productive directions,* rather than the search for and acceptance of simple dichotomous findings.

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[233] To be sure, Popper has concocted a concept of "existential" or "strictly universal" truths that don't have to go through the falsifiability regimen. However, it is impossible to determine what Popper considers the "demarcation" of an 'existential truth' and what is 'a conjecture' where he says in the most convoluted, confusing and bumbling fashion: "Strict or pure statements, whether universal or existential, are not limited as to space and time. They do not refer to an individual, restricted, spatio-temporal region. This is the reason why strictly existential statements are not falsifiable. We cannot search the whole world in order to establish that something does not exist, has never existed, and will never exist. It is for precisely the same reason that strictly universal statements are not verifiable. Again, we cannot search the whole world in order to make sure that nothing exists which the law forbids. Nevertheless, both kinds of strict statements, strictly existential and strictly universal, are in principle empirically decidable; each, however, in one way only: they are unilaterally decidable. Whenever it is found that something exists here or there, a strictly existential statement may thereby be verified, or a universal one falsified." *See* POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 49.

[234] Alana Flexman, Giuseppe Del Vicario & Stephan K.W. Schwarz, *Dark Green Blood in the Operating Theatre*, 369 THE LANCET 1972, 1972 (2007) (describing a patient suffering from a rare condition, sulfhaemoglobinaemia who had green-colored blood caused by massive ingestion of the migraine drug, sumatriptan. The condition (of green blood) results when sulfur is incorporated into the oxygen-carrying compound hemoglobin in red blood cells.).

[235] *Why is Spock's blood copper if he is half human?*, STACK EXCHANGE (October 20, 2015, 1:00 PM), http://scifi.stackexchange.com/questions/21996/why-is-spocks-blood-copper-based-if-he-is-half-human [http://perma.cc/TWA7-5CXK].

E. Popper and Chemistry: Elemental Obstacles

Let us now look to the world of chemistry. The science of chemistry holds all Carbon atoms have six electrons.[236] Upon this conviction (and convention) the entire field of organic chemistry is based.[237] Nevertheless, should we suddenly encounter something that looks like, smells like, tastes like and behaves like a carbon atom but has five electrons, defying conventional scientific knowledge, we have varying choices as to how we might deal with this. The organic chemist would search for a reason for the existence of this bizzaro particle, giving the new entity a new name to differentiate it from classical carbon. The Popperian might set about to rebuild a new system of chemistry, and in so doing demolish Mendeleevian classification of the elements on the way, wreaking havoc with how chemistry is practiced. Popper would avoid this problem by removing the science of identifying chemicals by atomic numbers from his purview of science. He considers this type of statement extra-scientific or "existential" and therefore, he claims the statement does not require falsification.[238] To him, Mendeleevian Chemistry[239] would fall into the category of non-empirical or *metaphysical* (something akin to religion, in Popper's view).

The existence of an atom with variant morphologies is indeed possible.[240]

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[236] In 1803 John Dalton, an English chemist, meteorologist and physicist, discovered that all atoms of a given element are identical in size, mass, and other properties. His first set of discoveries included Carbon. JOHN GRIBBIN, THE SCIENTISTS: A HISTORY OF SCIENCE TOLD THROUGH THE LIVES OF ITS GREATEST INVENTORS 368–69 (Random House 2002). *See also* Matt Williams, *John Dalton's Atomic Model,* UNIVERSE TODAY (Dec. 1, 2014), http://www.universetoday.com/38169/john-daltons-atomic-model [http://perma.cc/28E3-N6DV].

[237] Carbon has an atomic number of six, which is determined by the number of its electrons (or protons). *See* Elizabeth Rogers et al., *Fundamentals of Chemistry: Atomic Structure*, FALCON SOFTWARE, INC. (2000), http://chem.wisc.edu/deptfiles/genchem/sstutorial/Text4/Tx42/tx42.html [https://perma.cc/N6UV-US27]. When it was found that the number of neutrons could vary, the concept of 'isotopes' was devised to describe this phenomenon. GRIBBIN, *supra* note 236, at 372; *See also* BRYAN BUNCH & ALEXANDER HELLMANS, THE HISTORY OF SCIENCE AND TECHNOLOGY 409 (Houghton Mifflin 2004).

[238] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 48 ("Strictly existential statements, by contrast, cannot be falsified."). Interestingly, Popper calls the typing of chemicals by atomic structure "physics," as opposed to chemistry.

[239] The Mendeleev Periodic Chart (also called the Mendeleev Table of the Elements) was invented by Dimitri Ivanovitch Mendeleev in 1869. Mendeleev was a Russian scientist who "discovered that by arranging his elements in seven groups according to physical and chemical properties a remarkable order prevailed. The same properties repeated themselves after each seven elements. The table could be used to make predictions about the chemical behavior of elements, simply by examining the position of the elements on the chart." PHILIP CANE, GIANTS OF SCIENCE 118 (Grosset & Dunlap 1959).

[240] GRIBBIN, *supra* note 236, at 368–69, 372.

However, to imagine a chemical makeup where, let's say, carbon's atomic structure is not based on a six electron atom would require reformulation of Mendeleev's periodic table of elements, which is ludicrous, for this would not only crumble the science of organic chemistry on which it is based, but polymer chemistry as well. Indeed the isolation of benzene (an organic compound with six carbon and six hydrogen atoms) by Faraday in 1825[241] and Kekulé's discovery of its ring-shaped structural makeup, which revolutionized organic chemistry,[242] could only have been predicated on a surety of carbon's atomic makeup, i.e., that it has six electrons.

Let us take this thought further by selecting two elements to make a compound whose 'recipe' is predicated on the atomic number of each element. For example, by combining two atoms of hydrogen with one atom of oxygen, we can make water. Let us presume this experiment has been repeated by every inorganic chemistry student since Henry Cavendish first compounded water in 1784,[243] generating perhaps one hundred million repetitions of the experiments, all trying and succeeding in *proving* that H_2O is water.

The Popperian, who eschews certainty in science, is fully ready to accept that tomorrow, in some small town, call it Chelm, the experiment will go awry, and everyone in Chelm now requires two hydrogen atoms and two oxygen atoms to make water (the recipe for a different compound, elsewhere called hydrogen peroxide). The Popperian would start at once to reevaluate the notion of chemistry, and the chemist would hypothesize that atmospheric conditions in Chelm have been altered (from climate change, electromagnetic radiation, sun spots, etc.) such that the laws of nature for our universe no longer apply to that locality. The Homeland Security expert would infer that Chelm is under attack by terrorists who have the power to change the way Chelmites think, or that the enemy is playing havoc with the natural laws of the Universe, or both. This example is not made facetiously; rather it demonstrates how different scientists with different approaches can infer different causal mechanisms to explain the same phenomena[244] and explains the very real conundrum of how three different experts[245] can reach different conclusions in the same tort case,[246] leaving it to the hapless judge to sift out the competing viewpoints.[247]

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[241] THOMAS MARTIN, THE ROYAL INSTITUTION 31 (British Council, 3rd ed., 1961). *See also* GRIBBIN, *supra* note 236, at 418.

[242] *See* GRIBBIN, *supra* note 236, at 418.

[243] CANE, *supra* note 239, at 63-64.

[244] Thus, chemists would consider a single atom of Helium to also be a molecule, while a physicist would not. THOMAS S. KUHN, THE STRUCTURE OF SCIENTIFIC REVOLUTIONS 50-51 (The U. Chi. Press, 2nd ed. 1970).

[245] *See* Soldo v. Sandoz Pharms. Corp., 244 F. Supp. 2d 434 (W.D. Pa. 2003).

[246] *See* Joe Cecil, *Ten Years of Judicial Gatekeeping Under* Daubert, 95 AM. J. PUB. HEALTH S74, S76-S79 (2005).

[247] COHEN & NAGEL, *supra* note 68, at 5. Cohen and Nagels' book was published in 1934, the same year Popper's first edition of *The Logic of Scientific Discovery* was

This is not as far-fetched as it might seem. As Thomas Kuhn tells us, the interpretation of the same events by different scientists with different training is going to yield different results:

> An investigator who hoped to learn something about what scientists took the atomic theory to be asked a distinguished physicist and an eminent chemist whether a single atom of helium was or was not a molecule. . . . For the chemist the atom of helium was a molecule because it behaved like one with respect to the kinetic theory of gases. For the physicist . . . the helium atom was not a molecule because it displayed no molecular spectrum. Presumably both men were talking about the same particle, but they were viewing it through their own research training and practice. Their experience in problem-solving told them what a molecule must be.[248]

Even simple words have been known to produce confusion in scientists of different persuasions: Matthew Cobb recounts a story where Nobel Prize winner Joshua Lederberg (physiology) began a correspondence with physicist and Fermi Prize winner John von Neumann in 1955.

> The two men soon realized that each of them did not understand what the other meant by 'information', and that Lederberg eventually concluded that this was because they were thinking at very different levels. For biologists, he argued, the 'propagation and evolutionary elaboration, of complexity is 'self-evident'- they were interested in the detail of how such a system could work. The logician von Neumann, however, was 'looking for the foundations of an axiomatic theory of reproduction' – something much more abstract and not linked to biology at all.[249]

In sum, Popper lives in (and pontificates from) a neat black and white world which is strongly divergent from the "messy" world of biology and physiology. Moreover, to him, like to the Red Queen, words mean what *he* says they mean. That different scientists might view the same thing in different ways is a notion neither he nor his philosophy can fathom.

F. Popper and Religion: Popper's Alchemical Sciences

1. We C*an* Falsify Religion: Therefore, Per Popper's Rules: It Is 'Science'

We have just seen that it is impossible to falsify some very valid scientific statements, especially in biology and chemistry. This alone should invalidate

published in German.

[248] KUHN, *supra* note 244, at 50–51. *See also* ARNO C. BECHT & FRANK W. MILLER, THE TEST OF FACTUAL CAUSATION IN NEGLIGENCE AND STRICT LIABILITY 5 (Washington University Studies 1961) (illustrating how the principle also works with laymen in common legal cases, i.e, people embrace and interpret causation from their own experiential base).

[249] MATTHEW COBB, LIFE'S GREATEST SECRET, THE RACE TO CRACK THE GENETIC CODE 146 (2015).

Popper. But I will go further and use the converse approach. I will falsify statements which Popper claims cannot be falsified, definitionally and axiomatically: namely, those pertaining to religion.

The Popperian system discards notions that religion is scientific, claiming that what props up this ideology is merely belief and not objective proof.[250] Thus, under the rubric of falsifiability, Popper claims he can distinguish religion from 'science,' because religion cannot be falsified,[251] (i.e., tested and disproved).[252] We shall now falsify Popper's view that religion cannot be falsified using Popper's falsification method (not to disprove the scientific status of the religion asserted, but to disprove the viability of the falsification method itself).

The Popperian rejection of religion[253] makes no distinction among religions.[254] Since Popper's disdain we can pick any to disprove. Let's examine the religion of 'idolatry,' whose adherents believe that pagan statues are all-

[250] Anthony Flew is credited with being the originator of this approach. JAMES FRANKLIN HARRIS, ANALYTIC PHILOSOPHY OF RELIGION 30 (Springer Science & Bus. Media 2002).

[251] "Thus the problem which I tried to solve by proposing the criterion of falsifiability was neither a problem of meaningfulness or significance, nor a problem of truth or acceptability. It was the problem of drawing a line (as well as this can be done) between the statements, or systems of statements, of the empirical sciences, and all other statements—whether they are of a religious or of a metaphysical character, or simply pseudo-scientific. Years later—it must have been in 1928 or 1929—I called this first problem of mine the 'problem of demarcation'. The criterion of falsifiability is a solution to this problem of demarcation, for it says that statements or systems of statements, in order to be ranked as scientific, must be capable of conflicting with possible, or conceivable, observations." POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 51; *see also* Meyer, *supra* note 226 ("According to Popper, scientific theories can be distinguished from metaphysical theories because scientific theories can be falsified (as opposed to verified) by prediction and observation, whereas metaphysical theories cannot.").

[252] "It was Popper who advanced the idea that empirical falsification was a means for separating scientific theories from religious or philosophical theories." John Leonard, *Karl Popper and falsification of scientific theory*, (Apr. 1, 2010, 10:58 PM), http://www.examiner.com/article/karl-popper-and-falsification-of-scientific-theory [https://perma.cc/D22E-CUDU]. *But see supra* note 241 and accompanying text; *The Falsification Principle*, REVISION WORLD, http://revisionworld.com/a2-level-level-revision/religious-studies/philosophy-religion/attributes-god/falsification-principle [https://perma.cc/CCQ5-6RK5] ("Antony Flew applied the Falsification Principle to religious language and concluded that religious statements are nothing more than non-sensical utterances of little significance".).

[253] HACOHEN, *supra* note 142, at 68.

[254] "It is necessary to make it quite clear that I am speaking here about religion in a very general way. Although I always have Christianity in mind, I want to speak in sufficiently general terms to include all other religions. . . . I shall . . . extend the term even further." Rafe Champion, *Karl Popper on Religion, Science and Toleration*, CATALLAXY FILES (July 14, 2015, 10:33 PM), http://catallaxyfiles.com/2015/07/14/karl-popper-on-religion-science-and-toleration/ [https://perma.cc/PZT6-UPDC].

powerful. As most students of the Old Testament know, Abraham's father, Terach, was an idol-maker[255] and merchant of graven images.[256] One day, or so the story goes, Terach asked his son to mind the store.[257] When he returned it was in shambles, and all the idols, save one, were shattered into smithereens.[258] When Terach confronted his son, Abraham pointed to the largest idol, now holding a large ax, and said, "He did it!" Terach rejected this conclusion[259] along with the notion that the idol had any power at all, even to stop the idol-massacre. Abraham could have repeated the 'experiment' a dozen or more times and the result would have been exactly the same. His father could not logically accept the fact that the graven statue could actually perform the feat.

In this case, Abraham 'falsified' his father's religion. Hence, we see some religions are indeed falsifiable, and in fact, have been falsified. Thus, Popper can no longer say religion is not science because it is not falsifiable. In at least one instance it is, and was.

2. Faith-Based Science

We will now proceed to the notion of faith (or conviction), and may be surprised to learn it has a welcome home in science. We start by noting that science changes and new discoveries supplant older theories. At what point along the continuum 'the new' entirely replaces 'the old' as the 'prevailing wisdom' is the subject Thomas Kuhn's work.[260] Commenting on the ripe time for a scientific paradigm shift (which he calls a revolution), Kuhn acknowledges that at some level faith enters into the decision-making matrix of the scientific community:

> [T]he issue is which paradigm should in the future guide research. . . . A decision between alternate ways of practicing science is called for, and in the circumstances . . . . [a] decision of that kind can only be based on *faith*. . . . There must also be a basis, though it need be neither rational nor ultimately correct, for [that] *faith* . . . . Something must make at least a few scientists *feel* that the new proposal is on the right track, and sometimes it is only personal and inarticulate aesthetic considerations that can do that.[261]

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[255] Abraham Ben Isaiah & Benjamin Sharfman, *Torah Reading for Noach: Genesis, Ch. 11,* CHABAD.ORG, http://www.chabad.org/parshah/torahreading.asp?aid=9168&jewish=Noach.htm&p=7#showrashi=true [http://perma.cc/3URL-XVJ5].

[256] MOSHE WEISSMAN, THE MIDRASH SAYS 119 (Bnei Yakov Publications 1980).

[257] *Id.* at 243.

[258] *Id.*

[259] *Id.* at 120 ("The biggest . . . seized the ax and broke all the others."). *See also* MIDRASH RABBA GENESIS, VOL. 1, 310–11 (H. Freedman & Maurice Simon eds., H. Freedman trans., The Soncino Press 3d ed. 1983).

[260] *See generally* KUHN, *supra* note 244.

[261] *Id.* at 157–58 (emphasis added).

While there is something vaguely counterintuitive about Kuhn's sentiments, they are echoed by scientists of the caliber of Max Planck who said, "[t]he highest court is in the end one's own conscience and conviction—that goes for you and for Einstein and every other physicist—and before any science there is first of all belief."[262] This willingness to recognize belief as an element of, and not antithetical to, science is one thing that distinguishes Popper, the philosopher, from Planck, the physicist; neither Planck nor Kuhn are of the opinion that belief tarnishes the scientific validity of a proposition. In contrast, Popper believes that belief *per se* contaminates the purity and eternity of a scientific theory, although he accepts it as a necessary evil.[263] Since Popper believes all knowledge always changes and that we can never be sure when, we can only 'believe' something in science is true temporarily, i.e., until it is proven otherwise. Popper is quite explicit on this point:

> The old scientific idea of *episteme*—of absolutely certain, demonstrable knowledge—has proved to be an idol. The demand for scientific objectivity makes it inevitable that every scientific statement must *remain tentative for ever* [sic]. . . . Only in our subjective experiences of conviction, in our subjective faith, can we be 'absolutely certain.'[264]

How Popper's view of science ultimately differs from religion is not precisely clear, other than perhaps by formulating science as rebuttable presumptions. To the jurist (and Planck) this is a non-issue; we must begin with some basic premises in which we trust. Popper would undoubtedly be outraged to realize that in most courtrooms, the first principle of trust is in God.[265]

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[262] J.L. HEILBRON, MAX PLANCK, THE DILEMMAS OF AN UPRIGHT MAN: MAX PLANCK AND THE FORTUNES OF GERMAN SCIENCE 143 (Harvard U. Press 2000) ("The final basis, the last authority, for the fundamental principles of physical science lie deep in the individual," wrote Heilbron about Planck's view of the world. Although acknowledging this view introduces something 'non-scientific' into the base of science, this idiosyncrasy does not seem to torment Planck's view of science. Indeed, taken far enough, the basis of pure mathematics require elements of belief.).

[263] On one hand, Popper asserts that all knowledge is nothing but belief: "We obtain our knowledge by repetition and induction, and therefore by a logically invalid and rationally unjustifiable procedure, so that all apparent knowledge is merely a kind of belief—belief based on habit." Popper, Conjectures and Refutations, *supra* note 62, at 8. On the other hand, while acknowledging its inevitability, he states "In practical scientific research, this [notion of] belief [in the success of an experiment] is no doubt unavoidable and reasonable, there being no better alternative. But the belief is certainly unjustifiable in a theoretical sense, as I have argued (in section v)." *Id.* at 15.

[264] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 280. The *Daubert* court parrots Popper stating, "arguably, there are no certainties in science." Daubert v. Merrell Dow Pharms., Inc., 509 U.S. 579, 590 (1993).

[265] Indeed, while the Judges in *Kitzmiller v. Dover Area School District*, 400 F. Supp. 2d 707 (M.D. Pa. 2005), rejected the notion of any scientific underpinnings to Intelligent Design, some elements of Darwinian Evolution defy falsifiability. In other words, we have

Popper's view of provisional truth in science, therefore, leads us to the untenable conclusion that scientific knowledge can only be *believed* to be true, since there is always the possibility that tomorrow will bring about evidence of its falsity. The differential between Popper's science and religion is that religion requires eternal belief in its veracity, while science only demands temporary loyalty.

3. Science, Certainty, and Subjectivity

The net impact of Popper's work changed prevailing notions associated with science, that of objective 'certainty,' into one of continuous uncertainty.[266] Popper's own conviction in the tentative nature of science causes him to sound anything but scientific. Popper states:

> Science does not rest on solid bedrock. The bold structure of its theories rises, as it were, above a swamp. It is like a building erected on piles. The piles are driven down from above into the swamp, but not down into any natural or 'given' base; and if we stop driving the piles deeper, it is not because we have reached firm ground. We simply stop when we are satisfied that the piles are firm enough to carry the structure, at least for the time being.[267]

Since Popper furnishes us with no objective standard to determine when this state of satisfaction is reached, we are forced to use subjective assessments. Yet, Popper tells us that the word 'subjective' as applied (by Kant) to our feelings of conviction is not science, and without objective statements we trespass on what we call 'religion.'[268]

Popper, therefore, leaves the gatekeeper in a conundrum: an imposed responsibility to determine when evidence is scientifically solid enough to furnish firm ground for a jury to deliberate, yet without *objective* criteria upon which to make that determination–without even workable tests to discern what is or is not 'science.' Perhaps we can rely on the gatekeeper to apply rules for admissibility, but there are no rules to apply.

We are left with a litany of questions without the phantom of an outline of

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no mechanism to explain how life arose from non-life, although this is a cornerstone of the doctrine. *See* R.C. Lewontin, *Facts and Factitious in Natural Sciences*, *in* QUESTIONS OF EVIDENCE: PROOF, PRACTICE AND PERSUASION ACROSS THE DISCIPLINES 478, 481, 484 (James Chandler et al. eds., 1994); R.C. Lewontin, *A Rejoinder to William Wimsatt*, *in* QUESTIONS OF EVIDENCE: PROOF, PRACTICE AND PERSUASION ACROSS THE DISCIPLINES 504, 505, 507-09 (James Chandler et al. eds., 1994).

[266] MAGEE, *supra* note 194, at 220–24.

[267] POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 94.

[268] *Id.* at 23 ("The word [']subjective[']] is applied by Kant to our feelings of conviction"); *id.* at 22 ("[Kant] uses the word 'objective' to indicate that scientific knowledge should be justifiable"); *id.* ("Now I hold that scientific theories are never fully justifiable or verifiable, but they are nevertheless testable. I shall therefore say that the *objectivity* of scientific statements lies in the fact that they can be *intersubjectively* tested.").

an answer in sight: *Who* should determine what constitutes 'science'? Should it be a judge? The majority of scientists? The experts on either side? On what basis does the gatekeeper decide if the standards are met? Is it a quantitative test or a qualitative one? Popper's views only confuse the issues further.

IV: SO FALSIFIABILITY IS FALSIFIED: WHO CARES? THE CONSEQUENCES OF FALSIFIABILITY

Those who have attempted to vivify a moribund method of vetting scientific evidence (disproof as opposed to proof) have buried us deeper into the quagmire, thus generating contortions, confusion and contentiousness.[269] I submit I have falsified Popper's 'falsifiability' and hence disqualified it as the rubric to determine what is considered 'science.' However, a question remains as to the importance of this finding. Since we can easily use a search term and replace 'falsify' with 'verify' or some other paradigm, what difference does it make now to expose this false premise twenty years after it was planted in case law and the judicial mindset?

Before attempting to create another approach, we discuss the consequences of the previously enumerated flaws. In the following section I identify and address problems Popper created arising from his notions of deductivism, falsification and falsifiability.

A. Finality in Law and Science

Popper's viewpoint has been taken to support the false notion that science and law differ in their overall objectives (such as truth seeking) and their desire or need for finality.[270] Consequently, it has been said that "the objective of the law is justice; that of science is truth."[271]

Thus, the Court in *Daubert* opines: "[T]here are important differences between the quest for truth in the courtroom and the quest for truth in the laboratory. Scientific conclusions are subject to perpetual revision. Law, on the other hand, must resolve disputes finally and quickly."[272] This sentence, which sounds like a simple, uncontestable truism, presents yet another example of the 'willing suspension of disbelief' that lawyers employ when evaluating *Daubert*. Firstly, Popper designates science as the quest for 'truth,' but the law, too, is set up as a truth-seeking vehicle. Hence the maxim that a jury's verdict

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[269] Kaye, *supra* note 110, at 478–80. *See supra* notes 32-36 and accompanying text.

[270] Goodstein, *supra* note 109, at 52 ("Beyond the meanings of certain key words, science and the law differ fundamentally in their objectives. The objective of the law is justice; that of science is truth. These are among the highest goals to which humans can aspire, but they are not the same thing. Justice, of course, also seeks truth, but it requires that clear decisions be made in a reasonable and limited period of time. In the scientific search for truth there are no time limits and no point at which a final decision must be made.").

[271] *Id.*

[272] Daubert v. Merrell Dow Pharms., Inc., 509 U.S. 579, 596–97 (1993).

is to be based on a preponderance of the *credible* evidence.[273] Indeed, the only 'truth' that can be said is that science seeks knowledge, law seeks justice and perhaps philosophers seek 'truth.'

Moreover, the *Daubert* Court used a flawed method of analysis. When comparing temporal differences between law and science, the Court compares two different aspects of the process. Rather than comparing the general objectives of law with the general objectives of science and individual legal cases with individual experiments, the Court compares the general objectives of science with individual cases in law.[274] An *individual* case comes before the court. The concepts of finality and truth used in the court pertain to the *individual*, but the rhetoric used regarding science does not pertain to an *individual* experiment, but rather to *general* scientific maxims.

Thus, over swathes of time, both law and science change: the reasonable man has become the reasonable person, and Workman's Compensation is now Worker's Compensation.[275] Under normal conditions, we do not see a 'revision' of knowledge during or within either a pending case or a *single experiment.* As for diagnostic tests used in the practice of medicine, we do, in fact, require prompt finality when seeking a diagnosis or treating a patient, although researchers may be continually working on refining diagnostic methods.[276]

Furthermore, contrary to what Popper would have us believe, in the courtroom while things move quickly, the final verdict may well be temporary and subject to revision. Finality does not accrue until all appellate relief is exhausted (which may take years) and the law, itself, may be changed at any point during that time.[277] In fact, one might say that the legal appellate procedure invites revision more quickly and systematically than does science. We shall revisit this notion of a dichotomy between the search for truth in law and science in the final section of this paper when we are ready to redefine what is 'good science.'

In concluding this section, it must be said that while the Popperian approach may have worked in physics (or at least modern non-Newtonian physics),[278] its

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[273] AUSTIN J. FREELEY & DAVID L. STEINBERG, ARGUMENTATION AND DEBATE: CRITICAL REASONING FOR RATIONAL DECISION MAKING 128-9, 135 (Cengage Learning 12th ed. 2008).

[274] *See infra* note 352.

[275] Barbara P. Billauer, *Will Workers' Compensation Protect the Company Doctor?* N.Y L.J. (Feb. 1, 1985); Barbara P. Billauer, *The Legal Liability of the Occupational Health Professional*, 27 J. OCCUPATIONAL & ENVTL MED. 168, 185–88 (1985).

[276] Stephen K. C. Ng, *Does Epidemiology Need a New Philosophy? A Case Study of Logical Inquiry in the Acquired Immunodeficiency Syndrome Epidemic*, 133 AM. J. EPIDEMIOLOGY 1073, 1073-76 (1991).

[277] *See, e.g.*, Basso v. Miller, 40 N.Y.2d 233 (1976) (showing that requirements for notice in a premises liability negligence case were changed based on differing societal expectations, as a matter of policy).

[278] David H. Bailey and Jonathan M. Borwein, *Is Science 'Forever Tentative' AND 'Socially Constructed' NO WAY!*, HUFFINGTON POST (June 7, 2012, 6:25 PM, updated Aug.

run may be at an end. [279] At a recent conference held in Munich in December, many of the physicist attendees were surprised to learn how outmoded Popper's theories were and that:

> [F]alsificationism is no longer the reigning philosophy of science. Massimo Pigliucci, a philosopher at the Graduate Center of the City University of New York, pointed out that falsifiability is woefully inadequate as a separator of science and nonscience, as Popper himself recognized. Astrology, for instance, is falsifiable — indeed, it has been falsified ad nauseam — and yet it isn't science. Physicists' preoccupation with Popper "is really something that needs to stop," Pigliucci said. "We need to talk about current philosophy of science. We don't talk about something that was current 50 years ago."[280]

Even in the world of cosmology, 'falsifiability' is coming into disrepute.[281] Although once almost magical in its ability to generate falsifiable results, mathematics is no longer able to resolve all the disputes in the realm of theoretical physics.[282] We are now faced with the untenable conclusion that by using the falsifiability test we can reject neither of two prevalent theories of relativity and quantum theory, and we are no closer to resolving the dilemma than when it was first posed by Bohr and Einstein nearly one hundred years ago.[283] As Criton Zoakos notes, the current unprecedented controversy of superstring theory exists because we cannot even formulate testable predictions

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07, 2012), http://www.huffingtonpost.com/david-h-bailey/postmodern-science_b_1572737.html [http://perma.cc/85FR-UCK2] ("Moreover in most cases, modern 'falsified' theories continue to be extremely accurate within appropriate domains. Even today, over 100 years after Newton's mechanics and Maxwell's electromagnetic equations were "falsified" and supplanted by new physics, they remain the basis of almost all practical engineering and scientific computations, giving results practically indistinguishable from modern theories.").

[279] Kate Becker, *Does Science Need Falsifiability,* NOVA (Feb. 11, 2015), http://www.pbs.org/wgbh/nova/blogs/physics/2015/02/falsifiability/ [http://perma.cc/P38Z-8HBS] (questioning the testability of string theory and stating that "[i]t's possible that experimental tests of the predictions of string theory will never be within our reach.").

[280] Wolchover, *supra* note 59.

[281] David H. Bailey, *Is Modern Science "Socially Constructed" and "Forever Tentative"?*, SCIENCEMEETSRELIGION.ORG (Jan. 1, 2016), http://www.sciencemeetsreligion.org/philosophy/postmodern.php [http://perma.cc/85K5-JM9H] ("Copernicus' heliocentric theory was falsified and should not have been further considered, because it could not predict planetary motions as accurately as the traditional Ptolemaic system . . . . [Similarly,] Newton's theory was arguably falsified in the mid-19th century, when certain anomalies were noted in the orbit of Mercury. But it would have been irresponsible to have discarded Newtonian mechanics because of its overwhelming success in explaining a vast array of other phenomena . . . .").

[282] *Id.*

[283] *Id.*

even after forty years of effort,[284] "leading to the *conclusion that physics must now abandon the test of falsifiability*. . . . Leonard Susskind, director of the Stanford Institute for Theoretical Physics and a 'father' of string theory, was led to characterize the situation as a 'war,' accusing his opponents of practicing 'faith-based science.'"[285]

In sum, whatever Popper's rationale for pushing falsifiability, three facts emerge: (1) enough opponents to Popper exist[286] from various perspectives: legal,[287] epistemological, and philosophical, to render his approach questionable; (2) I have falsified (and hence invalidated) Popper's views on falsifiability by scientific examples; and (3) the science from which Popper's philosophy derived and was directed (quantum and Einsteinian physics), is not relevant to the science of the courtroom.

B. Courts Violate the Very Popper Rules They Rely on

Even assuming, *arguendo*, that there might be some validity to Popper's views, courts are not equipped to handle his methodology. In vetting scientific evidence, per Popper, judges merely need to ask if the evidence can be, and has been, falsified. However, the legal literature reveals that technically the courts are not playing by Popper's rules:[288] Under Popper's paradigm, every time a lie-detector case—or the use of DNA testimony or other accepted scientific evidence—comes before the court, they should need to subject it to scientific vetting anew, rather than rely on precedent. Since, per Popper, science constantly changes, one must entertain the notion that the science may have been falsified in the interim between the last precedent and this case. But that's not how it is done in our legal system. Instead, courts 'cheat.' They rest on prior judicial holdings—believing they are following Popper's formulations, when of course, they aren't.

Thus, Popper's 'temporary' scientific findings have become entrenched in law with all the power of *stare decisis*,[289] but without the constant attempts at falsification Popper demands.[290] Since judges are far more comfortable relying

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[284] Bailey agrees, but says after 25 years of effort. Criton Zoakos, *Time for the Big Questions*, LETO POSTSCRIPTS: CRITON ZOAKOS' EXPLORATIONS INTO THE ROOTS OF THE CRISIS IN WESTERN CIVILIZATION (Feb. 22, 2015), http://letopostscripts.net/2015/02/22/time-for-the-big-questions/ [https://perma.cc/5RBM-NTFJ].

[285] *Id.*

[286] *See* HAACK, *supra* note 73, at 139.

[287] *See* United States. v. Hines, 55 F. Supp. 2d 62, 74 n.7 (D. Mass. 1999) (noting that "the Court had simply taken the definition of science from Karl Popper, a definition that others have criticized as deriving from a culturally defined, time-bound paradigm."); HAACK, *supra* note 73, at 141.

[288] STRENGTHENING FORENSIC SCIENCE, *supra* note 5, at 108.

[289] *See generally* United States v. Green, 405 F. Supp. 2d 104 (D. Mass. 2005).

[290] See Manko v. United States 830 F.2d 831 (8th Cir. 1987) (setting the relative risk standard for epidemiological evidence at two, which has been almost idiotically accepted

on legal precedent than subjecting a scientific 'non-truism' to review each time it comes to court, we could hardly expect otherwise, as illustrated by Judge Gertner's lament, discussed earlier.[291]

C. Popperism Is Incompatible with Legalism

It is essential to realize that the Popperian emphasis on *disproof* unnecessarily distances science from law, which pivots on *proof*. Rarely, if ever, would plaintiffs or prosecutors enter a courtroom without assurance they could establish at least a prima facie case. Popper's view is different and idiosyncratic, philosophical, perhaps, but hardly 'scientific' in the world of the scientific practitioner. Moreover, it is flat out incompatible with legal practice.

1. Reliability: The *Sine Qua Non* of *Daubert* Cannot Be Determined from Negative Proof

Popper lays "stress on *negative* arguments, such as negative instances or counterexamples, refutations, and attempted refutations,[292] while the inductivist lays stress on '*positive instances'* from which he draws 'non-demonstrative *inferences*' and which he hopes will guarantee the 'reliability' of those inferences."[293] It appears that Popper is claiming the inductivist approach is incompatible with proving reliability.[294] Insofar as reliability is one of the key *Daubert* tests, by relying on Popper, *Daubert* becomes internally inconsistent. In other words, Popper's view undoes reliability, a critical requirement for admissible evidence. Incorporating Popper's views into *Daubert* only clouds the gatekeeper paradigm.[295] This concept has been delved into at length from a philosophical perspective by Susan Haack.[296] The impact of Popper's 'proof of the negative philosophy' when used in scientific research that is proposed as the basis for evidence or testimony in court is even more disturbing as we will see in the following section.

2. The Burden of Proof: A Review of Legal Basics from Within a Theoretical Framework

The Popperian view that there is no such thing as proof, only disproof, cannot be properly translated into law, for the legal analog would require that after the plaintiff asserts his or her claim, the burden would shift to the defendant to 'falsify' it, a state of affairs the law would deem intolerable.

In law, we expect the plaintiff to prove his or her claims, and not for the

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without review); HAACK, *supra* note 73, at 129.

[291] STRENGTHENING FORENSIC SCIENCE, *supra* note 5, at 108; *see supra* note 49 and accompanying text.

[292] HAACK, *supra* note 73, at 129; *see also* Dykes, *supra* note 57.

[293] HAACK, *supra* note 73, at 129.

[294] *See id*.

[295] *See id*. at 147 n.114.

[296] *Id.*

defendant to disprove the claims; indeed, generally speaking the defendant has no burden of proof at all.[297] Thus, if plaintiff's evidence is not believed or does not rise to the quantum necessary to convince a jury, the claim fails and the defendant need do nothing. We do not say that because the plaintiff brought in some evidence, however infirm it may be, the defendant must now disprove it, and we do not infer the plaintiff wins simply because the defendant did not bring in any evidence. However, similar to the plaintiff who must: (a) prove his or her claims; (b) by a certain quantum of evidence; (c) to the satisfaction of the decision-maker; and (d) whose decision may not be based on conjecture or speculation, so the experimental or laboratory scientist must prove his or her hypothesis, satisfying the elements of proof pertinent to her or his discipline by a certain quantum of evidence.[298] The elements of the game are identical under this view. The similar burden on lawyers and scientists contrasts with that imposed on philosophers, and perhaps theoretical physicists, who need not satisfy their claims with objective or empirical evidence. As Asher Peres once noted, "Unperformed experiments have no results."[299]

3. Default Positions in Law and Science: Popper's Theoretical Reversal of Unequal Burdens

A focus on disproof, essentially the Popperian approach, would stack the outcome in favor of a proponent, an outcome quite antithetical to the law where the plaintiff bears the burden or onus of proof (see below). This anomalous result of Popperian thinking can be seen in statistically-based research or evidence and testimony relying on it.

Restating the legal burden of proof in theoretical terms, in the context of a trial, the proponent of a legal claim (the plaintiff) is betting against an opponent (the defendant). As opposed to subjecting his or her claim against a single, straw man (which might occur in an administrative proceeding as we shall see in the statistical approach discussed below), we have trial by adversaries. The cards, legally speaking, are procedurally stacked against the proponent. To wit, the plaintiff bears the burden of proof. There are three options to the outcome in the adversarial system: (1) the plaintiff proves the claim; (2) the defendant disproves the plaintiff's claim (while not required, this is not prohibited either); or (3) neither side can prove their claim, i.e., the evidence is in equipoise in which case the plaintiff loses.[300] The probability that the plaintiff will win is one-third. The default position, (when the scales of credible evidence are not tipped in favor of one side) favors the defendant.

When evidence is based on statistical evidence or testimony (which is

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[297] ARIEL PORAT & ALEX STEIN, TORT LIABILITY UNDER UNCERTAINTY 130, 132 (2001) ("Yet under the P=.05 rule, this uncertainty should generally benefit defendants.").

[298] Butterworth, *supra* note 114.

[299] Asher Peres, *Unperformed Experiments Have No Results*, 46 AM. J. PHYS., 745, 745 (1978).

[300] Fleming James, *Burdens of Proof*, 47 VA. L. REV. 51, 52 (1961).

involved in most epidemiological studies), the Popperian approach leads to a counter-intuitive, legally untenable and disturbing result. Thus, restating the proof-paradigm in theoretical terms for the scientific arena, we can say that in science the scientist is betting only against herself or himself. This also holds true for empirical research that turns on statistics. The conventionally accepted statistical method requires couching a hypothesis in the negative (the hypothesis in this format is called 'the null hypothesis') and subjecting it to a falsifiability testing. Disproving the null hypothesis (the negative version of the hypothesis) results in a positive proof of the proposition, (i.e., disproving a negative is equivalent to proof of a positive proposition). In this methodology, the scientist has a fifty-fifty chance he will win or lose his bet (i.e., disproof of the hypothesis).

However, when the evidence is in equipoise, meaning there is not enough evidence to *disprove* the claim, we must infer that the proposal submitted for testing carries the day. In other words, if I can't affirmatively disprove my negative version of the hypothesis, then my (positive) hypothesis prevails. Thus we see that the default situation (where there is not enough evidence to tip the balance of proof) favors the proponent.[301] This is to say that disproof of the theory as negatively stated gives the proponent a greater chance of prevailing with what he or she truly wants to establish than if the proposal were submitted for testing in the straight-forward fashion used in law or sciences not dependent on statistics. The concept of falsifiability is turned on its head in statistics, because by way of the null hypothesis, we give the proponent a greater chance of prevailing. Counterintuitively, then, falsifiability actually makes the proponent's job easier. We may therefore conclude then that the Popperian scheme does not accommodate the stricter burdens the law imposes on the proponent. This situation cannot be stressed strongly enough, although attempts to muddle the effect of using the null hypothesis are pervasive.[302]

D. Falsifying Falsification: A Theoretical Introduction

I have illustrated instances of scientific propositions that cannot be falsified, and instances of 'religious' propositions that can be falsified above.[303] Now I will demonstrate instances where *true* scientific propositions *can* be falsified, leading to incorrect science, or the rejection of valid scientific knowledge.

The Popperian system may not be entirely at odds with law when single

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[301] *Id*.

[302] *See generally* Neil B. Cohen, *The Gatekeeping Role in Civil Litigation and the Abdication of Legal Values in Favor of Scientific Values*, 33 SETON HALL L. REV. 943 (2011).

[303] Another such example is astrology, a belief system which has indeed been falsified: does this make it science, albeit "failed science"? As Professor Massimo Pigliucci says, "Astrology, for instance, is falsifiable — indeed, it has been falsified ad nauseam — and yet it isn't science." Wolchover, *supra* note 59.

causes or single states are investigated in science. These instances can be translated into but-for causation. However, the Popperian system cannot handle multiple causal mechanisms. Thus, where two or more forces unite or act sequentially (e.g., joint or concurrent causation in law), or where two different results accrue from one cause, as may occur in chemistry, or where two actions are necessary to produce a condition as might arise in biology and physiology, the Popperian system breaks down, both in science and in law.

To recapitulate Popperian "wisdom," Popperism stands for the concept if "A" is not true because we have found even a single instance where it has been falsified, then the only alternative (or logical inference) is that "not-A" is true.[304] What Popper's system cannot tolerate is the possibility that *both* "A" and "not-A" are true. Notions of dual states and multi-causal mechanisms, key concepts in toxic tort and products liability, are incompatible with Popperian logic. This may not be a fatal flaw in examining cosmological forces at the inception of the Universe, but forensic paradigms must be compatible with notions of relevant science in today's world.

1. Dual States and Water Sports

Again, we shall disprove Popper again using his own method: Let's say that I have a hypothesis that water freezes at zero degrees centigrade. In real life, if I take an ice tray from my freezer, pick up an ice cube and measure its temperature, the thermometer will always read zero degrees Centigrade[305] or lower (assuming I am at sea level or nearby), which comports nicely with our personal experiences. The hypothesis is also falsifiable, so it qualifies as Popperian science and I can easily set up an experiment to falsify it.

In fact, I will. If I empty the ice tray in a bowl at room temperature, in a fairly short while, the ice will melt. I can wait until almost all the ice melts, remove the residual cubes and measure the temperature of the water in the bowl. It will read zero degrees. I have now falsified my hypothesis and must conclude water does not freeze at 0°C – after I have just proven that it does.

Eventually Popper must have figured out that this situation presents a problem because, indeed, water can and does exist both as a solid and a liquid at zero degrees (and as a gas and a liquid at 100 degrees).[306] Forty years after

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[304] In this convention, the null hypothesis is used in reverse. The scientist just casts his/her hypothesis in the negative, and by disproving it statistically (without showing why or how), the hypothesis is now "proven." Since the statistical null hypothesis doesn't define "not A," the proponent does not even have to propose an actual alternative hypothesis. *See* Daniel L. Rubinfeld, *Reference Guide on Multiple Regression, in* REFERENCE MANUAL ON SCIENTIFIC EVIDENCE 193 (Federal Judicial Center, 2d ed., 2000).

[305] *Salt and Ice*, ELEMENTARY SCIENCE PROGRAM, http://www.espsciencetime.org/student_life.cfm?subpage=295673 [https://perma.cc/Y9EW-DQBX] ("Fresh water freezes at 32 degrees F (0 degrees C).").

[306] Melting Point of Ice, AMRITA OLABS, http://amrita.olabs.co.in/?sub=73&brch=2&sim=30&cnt=1 [https://perma.cc/47YY-MU7N].

his *Logic of Scientific Discovery* was published, Popper returned to explain away some not clearly stated theoretical issues regarding water and its freezing point. He proposed a two-part solution to this conundrum: First, instead of calling the notion that water freezes at zero degrees a hypothesis, the conventional term,[307] he now calls it a 'definition,'[308] hence it can be changed at will without dissembling the theory that water freezes at zero degrees centigrade. (Interestingly, as we saw, he disdained the revised definitional approach when it comes to the biology of swans). In other words, Popper says where we have some substance with certain "atomic weights, melting points and similar properties as defining properties of materials [but since] there can be no water whose freezing point differs from 0°C; it would just not be water[, it would be something else]."[309]

Next, he says, "let us assume we have discovered water with a different freezing point . . . [t]he scientific hypothesis was that a liquid (no matter what you call it) with a considerable list of chemical and physical properties freezes at 0°C."[310] If this doesn't happen, Popper says, then "*we were wrong.*"[311] As to whether this "[i]s still to be called 'water'? *I assert that the question is totally irrelevant."*[312]

Philosophers Ernest Cohen and Morris Nagel addressed this very same issue in 1934. Cohen and Nagel introduce a dialogue between two popular philosophers, Mutt and Jeff who are also discussing the chemical properties of water.[313] Cohen and Nagel note that "Jeff's difficulty [like Popper's] arises from a misapplication of the sound logical principle of identity, that water is water and not something else."[314] But, they point out, to a scientist, water has a very specific meaning which arises by virtue of its chemical moniker H_2O—a "fact [which] enables us to understand many . . . properties of water, [including some] . . . which we would not have otherwise suspected."[315] To a scientist the term water is interchangeable with the scientific name, H_2O, or two hydrogen

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[307] Ioannis Lianos, '*Judging' Economists: Economic Expertise in Competition Law Litigation: A European View, in* THE REFORM OF EC COMPETITION LAW: NEW CHALLENGES 185, 269 (Ioannis Lianos & Ioannis Kokkoris eds., Kluwer Law International 2010).

[308] Popper however is notoriously loose in his use of scientific definitions. He uses the term "class" of mammal to convey "category," and illustrates an unfamiliarity with or lack of respect for the scientific system of biologic classification (the Linneaen system) in which "class" is a term of art with a precise meaning. POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 43–44.

[309] POPPER, POPPER SELECTIONS, *supra* note 79, at 124-25.

[310] *Id*. at 125.

[311] *Id*.

[312] *Id*.

[313] COHEN & NAGEL, *supra* note 103, at 383.

[314] *Id*.

[315] *Id*.

atoms and one oxygen atom combined in a certain way.[316] In other words, the substance's chemical name defines its properties, and hence the (scientific) name is hardly irrelevant; the scientist cannot simply call the substance C_3PO or R_2D_2 because it behaves in an unanticipated fashion as Popper would have us do.

Let us reframe the hypothesis to demonstrate: The molecule H_2O freezes at 0^oC. If Popper were to measure the temperature of the pool of recently melted (liquid) H_2O, he would discover it would be 0^oC, just as Joseph Black,[317] the Scotch chemist and physician, demonstrated about 250 years ago.[318] Now, Popper may think he has disproved his hypothesis, but he has not, because zero degrees *is* the freezing point of H_2O.

Popper is now faced with admitting that "either my criterion of demarcation is refuted, or we have to admit the possibility of discovering water whose freezing point is other than 0^oC,"[319] i.e., one he doesn't know. Unfortunately, a statement that we have water whose freezing point we don't know, and one we cannot disprove, is neither scientific, nor capable of falsification. Popper can not very well say what's in the bowl isn't H_2O (that it's something else) because analytically it verifiably *is* H_2O; and he can't (not in the world of real science, anyway) say he falsified the hypothesis and disproved the notion that H_2O freezes at zero degrees centigrade (even though it sure looks like he has), because we have shown that the contrary is also true: at zero degrees water can also be a liquid.

However, in the real world of science, we can legitimately conclude that H_2O can live in two states at the same time (or temperature), an increase in our

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[316] Popper has a problem here. He first says that if we find something that is supposed to be water, but doesn't act like water, we can call it something else. Then, Popper contradicts himself. He acknowledges that "we can use signs which are not proper names but which to some extent are interchangeable with proper names or individual co-ordinates." Thus, he admits the chemical descriptor is 'H_2O' is a universal concept or name which refers to water, which he considers of fundamental importance. But here is Popper's problem: if 'H_2O' doesn't act like water, we very well can't call it something else. So he must explain himself. And here he goes into a very confusing diatribe on the use of different types of names and definitions, noting that definitions, (e.g. the term "mammal'), might give rise to confusion, finally concluding by telling us that the difference between individual and universal concepts "would be of very little value . . . ." In the end, using a verbal sleight of hand, he tries to distract us from the fact that if we find H_2O (which most of us would call water) not acting like water, we cannot simply rename it, we have to look for an alternative explanation, which in turn leads us to a duality of findings, i.e. that water can exist as a liquid and a solid at 0 degrees centigrade. POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64 at 43-44.

[317] Popper was familiar with Black's work. In fact, he cites to Black's "Lectures on the Elements of Chemistry." POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 62 n.1.

[318] GORE, *supra* note 18, at 529–30. Dr. Black made this discovery in 1761.

[319] POPPER, POPPER SELECTIONS, *supra* note 79, at 125.

pool of scientific knowledge. And now we can proceed to expand our scientific knowledge further by finding out *why*, a realm of investigation that would be foreclosed if we were to follow Popper's routine.

Let us further demonstrate what Popper and his science are missing. Not only can I get my H_2O molecule to live in two alternative states at the same time (e.g., frozen and liquid), but I can teach my molecule new tricks. I can get it to remain a liquid as low as (or even lower than) 40^oC if the water is very pure (this is called supercooled water),[320] and there is no kernel of something for the first ice crystal to glom on to.

So here we have three mutually exclusive and yet mutually true hypotheses existing simultaneously: Water freezes at zero degrees centigrade; Water doesn't freeze at zero degrees centigrade; Water is a liquid well below zero degrees centigrade (or to phrase it differently, the melting point of H_20 is 0 degrees C; the freezing point of H_20 is 0 degrees C; the freezing point of H_20 is well below 0 degrees C; all of the above are true.).

Thankfully, Joseph Black did not reject his hypothesis[321] as Popper would have him do.[322] What he did was investigate further and discover a new phenomenon called 'latent heat'—a discovery that later became important in the development of the steam engine.[323]

In summary, the Popperian system of deductive thought is single-minded; if not this, then that, and if not that, then neither. But the science of real life (that which finds its way into the courtroom) does not behave the way Popper's idealized universe of quantum physics does. Indeed, duality is a common feature of our everyday lives.

2. Multiple Causation: The Dangers of Dust

In medicine, multi-causal effects are of key concern, both to doctors and public health practitioners: How much of tuberculosis causation is attributable to the bacillus and how much to poor health and socio-economic conditions? How will an immuno-compromised patient react to a certain drug or vaccine? Is a patient's liver cancer a metastasis with a short prognosis, or due to concurrent ingestion of Extra Strength Tylenol and alcohol, giving the patient a longer prognosis?

In the courtroom, duality of states or causes arises in multiple (legal) causation and multi-causal negligence cases, be it legally imposed such as joint

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320 *Chemists Discover Freezing Point of Supercooled Water*, MIT TECHNOLOGY REVIEW (July 11, 2011) https://www.technologyreview.com/s/424639/chemists-discover-freezing-point-of-supercooled-water/ [https://perma.cc/WJ85-C96P].

321 GRIBBIN, *supra* note 236, at 248.

322 It seems Popper was well aware of Black's experiments, citing to it in THE LOGIC OF SCIENTIFIC DISCOVERY. See supra note 64, at 62 n.1; Joseph Black, Lectures on the Elements of Chemistry: Vol. 1, NIH U.S. NAT'L LIBRARY OF MEDICINE (1807) xxix, 116,189, 193, 195-197, available at https://collections.nlm.nih.gov/catalog/nlm:nlmuid-2543060R-mvset.

323 GRIBBIN, *supra* note 236, at 252-253.

and several liability or factually derived, such as concurrent causation and dual actors. The concept may apply in criminal cases where clues identifying a defendant are not inconsistent with ruling out the identity of a second or third suspect. In short, we must conclude that the notions of falsification are unsuited to either the legal, biological or chemical forensic investigation.

The world of biology is replete with instances of dual causation that affect the way the body or our environment behaves. For example, certain aerobic bacteria, which require oxygen to live, can, under certain conditions, morph into anaerobic bacteria, called *facultative anaerobes*[324] meaning they can also survive without oxygen. This fact is easy to verify but can be most difficult to falsify.

Another example comes from a field of medicine very relevant to toxic tort causation: In 1870 John Tyndall discovered that dust transmits infectious diseases.[325] By demonstrating that optically pure air was incapable of developing bacterial life, he was able to *infer* that dust spread bacterial infections.[326] His discoveries had "great value in combating the doctrine of the spontaneous generation of life [although it] met with much criticism and some ridicule" at the time.[327] Eventually, Tyndall's science was accepted. His celebrated Friday Evening Discourse on the topic (given on January 21, 1870) entitled *Dust and Disease*[328] was more portentous than he realized.[329]

However, Tyndall's discovery is easily falsifiable. To falsify Tyndall's discovery, we need only take a certain amount of dust, sterilize it and then expose a respectable quantity of test subjects to our sample. If the dust is of a certain size and shape, the test subjects will come down with serious ailments, from pneumonia to fibrotic lung disease, to asthma to alveolitis and even cancer.[330] In this experiment, we would have falsified the notion that the dust is a carrier of bacteria-causing disease. We proved that dust, itself, causes disease, and in some cases the exact same type of harm (e.g., an inflammatory response)[331] as bacteria.[332] Indeed we would be right. Depending on the size

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[324] "Facultative anaerobes . . . have two alternative energy-yielding mechanisms at their disposal. In the presence of oxygen, they employ aerobic respiration, but they can employ fermentation if no free oxygen is present in the environment." ROGER STANIER, ET. AL., THE MICROBIAL WORLD 309 (Prentice-Hall, Inc. 3rd ed., 1970).

[325] BULLOCH, *supra* note 202, at 113-117.

[326] MARTIN, *supra* note 241, at 52

[327] *Id.*

[328] *Id*.

[329] *Id*.

[330] *See generally* ANTHONY SEATON ET AL., CROFTON & DOUGLAS' RESPIRATORY DISEASE, (1969).

[331] W. KEITH MORGAN & ANTHONY SEATON, OCCUPATIONAL LUNG DISEASES 79-86, 103-133, 196-211 (1984).

[332] ABUL K. ABBAS, ET AL., CELLULAR AND MOLECULAR IMMUNOLOGY 342 (7th ed., 2011).

and shape of the dust particle, many dust particles fit the necessary disease-producing criteria: coal, wood, quartz, cement, nickel, beryllium, lead, volcanic ash, pollen, sand, and of course, the ubiquitous cotton would all qualify, along with the better known asbestos and silica.[333]

In this case, falsification deprives us of an important scientific concept–the germ theory of disease–since we would be required to conclude that the dust itself, rather than microbes which ride on it, is the causative agent. Tyndall's conclusion that dust spreads bacterial infection was, of course, true, but it was not the only possible or valid conclusion.

This duality of dust as independently capable of causing disease and as a carrier of biological disease agents (mold, fungi and bacteria) was well known by 1959 when Popper's English (rewritten) version of *The Logic of Scientific Discovery* was published.[334] Paul Kotin, a senior vice president for Health, Safety and Environment for the Johns-Manville Corporation had in his library the 1954 publication *Dust is Dangerous*[335] which documents the dust-causing mechanism of disease by fibers, including asbestos.

V. AN ALTERNATIVE UNIVERSE: WHAT IS SCIENCE?

So, if falsification does not tell us what 'science' is,[336] let alone what 'good science' is, then what, the gatekeeper may ask, can?

A. Addressing the Needs of the Gatekeeper: Redefining Science

It is useful here to review the notions of 'science' through the last century. In 1911 the Encyclopedia Britannica stated: "Science may be defined as ordered knowledge of natural phenomena and of the relations between them."[337] In 1955, Marshall Clagett tells us, "[s]cience comprises, first, the

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[333] *Hazard Prevention and Control in the Work Environment: Airborne Dust: Chapter 1 - Dust: Definitions and Concepts*, THE WORLD HEALTH ORGANIZATION (Aug. 1999), http://www.who.int/occupational_health/publications/en/oehairbornedust3.pdf [https://perma.cc/9E2U-RQRT].

[334] *See supra* notes 120-123 and accompanying text.

[335] *See* C.N. DAVIES, DUST IS DANGEROUS 12-15 (Faber and Faber Ltd. 1954) ("When fine coal dust has accumulated beyond a certain stage, localized areas of fibrous tissue, impregnated with coal dust, develop and coalesce, leading to a serious condition known as progressive massive fibrosis."); *id*; 16-17 (regarding cancer). Paul Kotin's copy (with his stamp on the inside cover) resides in the author's personal library.

[336] An example of dual causal requirements is found in child development research where benefits of positive reinforcement were observed only in children with a particular genetic makeup. Without the technological capacity to examine the genetic contribution, the hypothesis of the beneficial impact of positive reinforcement would have been disproved (falsified), and the (flawed) conclusion or inference would have been environmental modification is useless. *See* Marinus H. van IJzendoorn, et al., *Gene-by-environment experiments: a new approach to finding the missing heritability*, 12 NATURE REVIEWS | GENETICS 881 (Dec. 2011).

[337] DAMPIER-WHETHAM, ENCYCLOPÆDIA BRITANNICA, *supra* note 68, at 396 (University

orderly and systematic comprehension, description and/or explanation of natural phenomena and, secondly, the [mathematical and logical] tools necessary for the undertaking."[338] And in 1993, shortly before *Daubert* was decided, Paul Hoyningen-Huene a physicist and Director of the University of Hanover's Center for Philosophy and Ethics published a detailed and useful list of what science is:

- Science studies nature, or the world.
- Science aims at an understanding of nature or the world which captures its order with maximal precision and universality.
- Science's orientation toward this goal demands that it search for a set of propositions exhibiting maximal internal coherence . . . with nature or the world.
- Science is mostly detail work; it strives toward understanding of nature or the world by way of a precise understanding of the individual aspects of nature or the world.
- Science proceeds empirically; in other words, the acceptability of propositions is strongly regulated by observation and experience.
- Therefore, there exists a universal characterization both of the production methods of scientific knowledge and of the type of arguments that may be used in support of claims to such epistemic status.[339]

Subject to one modification, that the first criterion be amended to read, "science studies nature or the 'finite' world," I suggest that the definition of science as the building block for a Gatekeeper paradigm be predicated on Hoyningen-Huene's formulation. Hence, I propose the following definition of 'science' for use in the legal arena:

This formulation, while guiding us as to what is eligible to be considered 'scientific' as opposed to new-ageism in any of its varieties, still leaves us adrift in deciding what 'good science is and how it is done. Since we have rejected Popper and his falsification scheme, we need to substitute another approach.

What is science?
Science is verifiable knowledge about the natural or finite universe
Science is the pursuit of knowledge that studies the natural world or finite universe by an organized and reproducible methodology, seeking to a) categorize, b) organize, and c) understand the modality of working and interworking of its component parts. It aims to produce verifiable (objective) results.

Press, 11th ed., 1911).

[338] MARSHALL CLAGETT, GREEK SCIENCE IN ANTIQUITY 4 (Collier Books 1955).

[339] PAUL HOYNINGEN-HUENEV, RECONSTRUCTING SCIENTIFIC REVOLUTIONS: THOMAS S. KUHN'S PHILOSOPHY OF SCIENCE 23 (University of Chicago Press 1993).

B. Understanding Verifiability

Philosophers Cohen and Nagel advise us that "a hypothesis must be *capable of verification*."[340] They remind us that at the time a hypothesis is developed it may be impossible to verify[341] because of practical or testable difficulties.[342] Popper would call this pre-verified hypothesis "metaphysics."[343] But Cohen and Nagel indicate that a hypothesis is frequently incapable of immediate verification and this is not an impediment to its scientific standing, a diametrically opposite view, and "while it can never be *demonstrated if* [a proposition] asserts a truly universal consequence, it must be *verifiable*."[344] The notion of proof by 'verifiability'[345] is called 'positivism.'[346] Popper considered himself a staunch opponent of the school; the cosmologist and physicist, Stephen Hawkings, considers himself a member.[347]

The post-scientific revolution demonstrates that the mission of scientists is *verification*, meaning that they attempt to prove the truth of a proposition by evidence or testimony. In other words, the plain dictionary meaning would have scientists confirm or substantiate a contention or ascertain the truth or correctness of a hypothesis "by examination, research, or comparison," of a claim.[348] In this regard, the principles of science (and we shall exclude the fields of cosmology, quantum mechanics and Einsteinian physics[349]) and law are remarkably similar in objectives: to prove or confirm (an allegation or proposition). Thus, the dictionary meaning of 'verifiability' in law is virtually synonymous with its general meaning: to act as ultimate proof or evidence of

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[340] COHEN & NAGEL, *supra* note 68, at 211; *id.* at 25.

[341] *Id*. at 211.

[342] Roger Penrose, *The Quantum Nature of Consciousness*, YOUTUBE, https://www.youtube.com/watch?v=3WXTX0IUaOg [http://perma.cc/F8YH-T4GR].

[343] *See* POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 68, at 13, 315; POPPER, CONJECTURES AND REFUTATIONS, *supra* note 62, at 1.

[344] COHEN & NAGEL, *supra* note 68, at 211.

[345] In 1894, amid a ruckus of what constitutes 'scientific proof' in a legal context (see TAL GOLAN, LAWS OF MEN AND LAWS OF NATURE 254 (Oxford University Press 2001)), Dr. Daniel Brinton, the president of the American Association of the Advancement of Science stated: "The one test of scientific truth is that it . . . must not only be verified but always verifiable." See Editorial "Science," 71 SCIENTIFIC AMERICAN, at 243 (1894).

[346] MICHAEL FRIEDMAN, RECONSIDERING LOGICAL POSITIVISM xiv (Cambridge University Press 1999).

[347] As Roger Penrose has said: "I, on the other hand, am a positivist who believes that physical theories are just mathematical models we construct, and that it is meaningless to ask if they correspond to reality, just whether they predict observations." PENROSE, *supra* note 46, at 169.

[348] *Definition of Verify*, DICTIONARY.COM, http://dictionary.reference.com/browse/verifiability [http:// perma.cc/N8YH-HP49].

[349] Although Einstein did write that "The physicist is concerned with the question as to whether the theorems of geometry are true or not." ALBERT EINSTEIN, THE MEANING OF RELATIVITY 8 (AcademicComplete 2001).

something.[350] (It should be noted that the origin of the word 'verification' derives from the Latin *verus* meaning 'true,'[351] and certainly the tenor of law is to establish truth by verification or proof). Thus, notwithstanding attempts to differentiate the fields of science and law (and to be sure there are differences), the quest for truth and the approach for truth-seeking is far more compatible than either *Daubert* or misguided jurists would have us believe.[352]

Indeed, the method "modern" scientists use to establish their claims is verifiably demonstrative experiments, such as those Sir Humphrey Davy used to create the new science of electro-chemistry in 1806.[353] Falsification was undertaken during the early years of science, mostly by prominent scientists whose reputations and theories were being upstaged by some young upstart or a rival[354] whose (verificationist) theory was being attacked.[355] The nature of these attacks, often *ad hominem* set back the cause and progress of science by decades if not centuries.[356] The proponent of a new theory was generally only

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[350] *See generally* POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 64, at 48.

[351] *Definition of Verifiable*, VOCABULARY.COM, www.vocabulary.com/dictionary/verifiable [https://perma.cc/W7BS-3Z2V] ("Something is scientifically verifiable if it can be tested and proven to be true. Verifiable comes from the verb verify, 'authenticate' or 'prove,' from the Old French verifier, 'find out the truth about.').

[352] *See* STRENGTHENING FORENSIC SCIENCE, *supra* note 5, at 86 ("Since as far back as the fourteenth century, scientific evidence has posed profound challenges for the law. At bottom, many of these challenges arise from fundamental differences between the legal and scientific processes. . . . *The legal system embraces the adversary process to achieve "truth," for the ultimate purpose of attaining an authoritative, final, just, and socially acceptable resolution of disputes.* Thus law is a normative pursuit that seeks to define how public and private relations should function. . . . *In contrast to law's vision of truth, however, science embraces empirical analysis to discover truth as found in verifiable facts.*") (emphasis added).

[353] MARTIN, *supra* note 241, at 16.

[354] PAUL DE KRUIF, MICROBE HUNTERS 205 (1953) ("The great medical congresses of those brave days were exciting debating societies about microbes . . . .").

[355] *Id*. at 202 (details the fight between proponents of the white blood cells versus the red blood cell partisans, as to which is involved in immunity. "I have demonstrated that the serum of rats kills anthrax germs . . . shouted Emil Behring, and all the bitter enemies of [Ilya] Metchnikoff sang Aye in the chorous. . . . Neither side would budge from this extreme prejudiced position. For twenty years both sides were so enraged that perhaps our [red] blood [cells] *and* our phagocytes [white blood cells] might work together to guard us from germs . . . . That fight was a kind of magnificent but undignified shouting match of 'You're a liar—On the contrary, it's you that's the liar.'").

[356] *See generally* RUTH FOX HUME, GREAT MEN OF MEDICINE 21 (Random House 1961) ("Harvey's theory was such a complete break with the traditional—Galen's view . . . . To assert that blood moved in a circle was bad enough, but to claim that the *same* blood was used over and over again was not only an absurdity, but an insult to nature herself . . . ''twas believed by the vulgar that he was crack-brained and all the physicians were against him' wrote a historian of the times." (quoting Fraser Harris, *The Man Who Discovered the*

successful during his lifetime if well-backed, well-heeled or well-liked.[357] Thus when the abbé Nollet attacked Franklin's view of electricity, it was a massive public relations campaign by his friends and colleagues that saved Franklin, his reputation and the modern understanding of electricity—and their refutation was done in letters and articles, not experiments.[358]

Thus, in the world of experimental science, we talk of testability by experiment as a means to *verify* a hypothesis; a valid "a hypothes[is] must *be capable of verification*." [359] As one scientist noted:

> Scientists are usually very good at designing experiments to test theories. What it . . . means to be scientific brings us right back to . . . experimentation and experimental design. If I [as a scientist] propose a scientific explanation for a phenomenon, it should be possible to subject that theory to an empirical test or experiment.[360]

> We invent theoretical entities and explanations all the time, but very rarely are they stated in ways that are falsifiable. It is also quite rare for anything in science to be stated in the form of a deductive argument. Experiments aren't often done to falsify theories, but to provide the weight of repeated and varied observations in support of those same theories. Sometimes we'll even use the words verify or confirm when talking about the results of an experiment.[361]

The language of Thomas Martin, a Historian for the Royal Institution, is illustrative: "In a series of beautiful experiments Faraday *proved*, by systematic comparison of its chemical, magnetic and other effects, that 'electricity whatever may be its source, is identical in nature.'"[362] This formulation, proving a certainty about the nature of electricity is an anathema to Popper. Although it may be theoretically possible to falsify Faraday's discoveries, it is difficult to conceive that falsification could happen, as should it happen, along

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Circulation of the Blood, 82 THE POPULAR SCIENCE MONTHLY 454, 459 (1913))). *See also id.* at 50 (attacking Jenner); *id.* at 64 (attacking Laennec); *id.* at 79, 82 (attacking Morton); *id.* at 118, 122 (attacking Lister, "who's own colleagues refused to have anything to do with his methods."). See especially the portion addressing Laennec.

[357] Barbara P. Billauer, *Benjamin Franklin: Scientist-Statesman and the Father of Scientific Statecraft*, 12 PROCEEDINGS OF THE POLICY STUDIES ORGANIZATION 4-5 (Oct. 1999), http://www.ipsonet.org/proceedings/wp-content/uploads/2012/07/Paper-12-Benjamin-Franklin1.pdf [https://perma.cc/3YMS-VYK3] (citing generally Esmond Wright, Benjamin Franklin, His Life as He Wrote It (Harvard University Press 1990).

[358] *Id*.

[359] COHEN & NAGEL, *supra* note 68, at 211; BERNARD, *supra* note 112, at 37 ("We must trust our observations or our theories only after experimental verification . . . .").

[360] Dan Gezelter, *Being Scientific: Falsifiability, Verifiability, Empirical Tests, and Reproducibility*, OPEN SCIENCE FORUM (Dec. 1, 2009), http://www.openscience.org/blog/?p=312 [https://perma.cc/MWJ2-KZ2A].

[361] *Id*.

[362] MARTIN, *supra* note 241, at 38 (emphasis added).

with it would tumble the whole derivative science of electrical engineering.[363]

In summary, both law and science require empirical and verifiable facts on which we rely, which is called 'evidence' in both fields, and which contributes to our view of 'truth.' In science, the evidence arises via experiment and direct sensory observation; in law, evidence is adduced via testimony based on first-hand knowledge, direct sensory observation and expert testimony based on 'good science.' Thus, it can be said that 'truth is truth,' and science's view of truth is no different than the law's,[364] notwithstanding the proliferation of opinion to the contrary that has leaked into legal common-think.

C. Redefining 'Good Science'

Perhaps then, the notion 'what is science' might be ruminated on by a philosopher, but what is 'scientific,' the critical question that plagues the *Daubert* judges, can only be answered by a scientist, who actually 'does' science.[365]

The history of modern science demonstrates that every new piece of knowledge is built on the presumption that science on which it relies is sound[366] to generate new knowledge without constantly looking backward for errors. This principle is reflected in the term *valid* (a term, haphazardly bandied about in *Daubert* and co-mingled with the term *reliable*). Disentangling the two terms is one of the critical requirements for forging a new forensic system evaluating scientific evidence for admissibility. *For now, it is sufficient to realize there can be no 'valid' science without it being somehow related to pre-existing scientific knowledge—and this pre-existing knowledge must engender such profound trust that we call it* '*true*.' (If Popper is correct, however, there can never be new and *valid* science, since we can never be sure the basis upon which the new science is developed will someday become disproved).

In 1878 George Gore,[367] (an electro-chemist elected as a Fellow to the Royal Society of Britain in 1865) published a book entitled, "The Art of Scientific Discovery," the stated purpose of which was to advise young people who have

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[363] *Id*. at 50.

[364] Albert B. Logan, *May A Man Be Punished Because He Is Ill?* 52 A.B.A. J. 933 (1966) ("The hallmark of justice is the eternal search for truth."). *Cf.* The claim that *only* science involves the truth for search made by D. Allen Bromley in his Address at the 1998 Annual Meeting of the American Bar Association on Aug. 2, 1998. *See* Goodstein, *supra* note 109, at 52 n.19.

[365] This is reminiscent of Shimony's admonition to a would-be philosophy of physics student to study physics first before its philosophy. Prof. Terno, *supra* note 213.

[366] As Isaac Newton famously declared, "If I have seen further it is by standing on the shoulders of giants," CANE, *supra* note 243, at 98.

[367] SIDNEY LEE, Gore, George, *in* DICTIONARY OF NATIONAL BIOGRAPHY, 1912 SUPPLEMENT 2 (Smith, Elder & Co. 1912).

decided to pursue a career in science, on how to do it.[368] The extensive book comprehensively reviews every aspect of practical science along with furnishing theoretical implications, philosophical musings and providing historical example where appropriate.[369]

Gore tells us that the objective of good science is critical evaluation of all evidence i.e., testing and verification along with logically assessed results.[370] For starters, he gives gatekeepers their first rules: 1) "A true scientific statement," Gore says, "is one which does not contradict any of the facts or laws of nature, but which agrees with and is supported by all of them."[371] 2) "So-called facts cannot be relied on as facts, unless they have been at one time or another carefully *verified*."[372] Gore suggests that if we cannot trust the chemist who supplied the materials we must test the substances. 3) "That which is not to be depended on is not science; assumptions and hypotheses are also not strict science, but only a means to discovering it[; and 4)] Trustworthiness [qualitative truth] is the first object, and accuracy [quantitative truth] is the perfection and final aim of science."[373]

Gore elucidates and distinguishes between qualitative truth (what we might call validity) and quantitative truth or accuracy (what we might call reliability), noting that qualitative truth is far more important than quantitative truth. 1) "A qualitative truth is not one of degree; it is absolute. In a qualitative sense, a thing must either be or not[; and][374] 2) "The idea of accuracy is a quantitative one, and accuracy may exist in all degrees from nothing to perfection."[375]

There is a story told about the physicist Abner Shimony who was approached by a philosophy graduate wanting to do a PhD in the philosophy of physics [specifically quantum mechanics]. Shimony told the student that he first needed a PhD in physics, and then he might qualify to study its philosophy.[376] This simple exchange would insinuate that—at least in the mind

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[368] Gore's book is painstakingly researched, including a section on women scientists and wives of scientists involved in their research along with the work of hundreds of scientists from all branches. GORE, *supra* note 18.

[369] "As the object of all scientific research is the attainment of truth, and as mistake hinders that object, knowledge of error and the means of avoiding or correcting it is often a condition of success in research." *Id*. at 105; Gore believed in scientific truth noting that facts, which are the basis for all science are truths that are lasting in nature ("forever"). He well-recognizes mistakes have been made, (listing dozens by name and error) and advises that upon being presented with a fact, the responsible scientist will *verify* it, going so far in some cases to personally repeat all experiments relied (e.g., Faraday). *Id*. at 8, 82, 85.

[370] *See supra* notes 359-364 and accompanying text.

[371] GORE, *supra* note 18, at 87.

[372] *Id*. (emphasis added).

[373] *Id*. at 148.

[374] *Id*. at 150.

[375] *Id*.

[376] Communication from Prof. Daniel Tenro, a student of Prof. Asher Peres, to author (Feb. 15, 2016) (on file with author).

of scientists—only scientists are qualified to determine the philosophy of the *métier*. The pointers put forth by George Gore, himself a scientist, are a truer representation of how scientists themselves conceive of 'doing science'—by way of experimentation, verification and evidence of both qualitative truth (validity) as well as quantitative accuracy (reliability). Gore's points are also descriptive of how science is actually practiced today. *Daubert* fails to account for two of Gore's features—substituting falsifiability for verifiability and ignoring validity entirely. As the critique of Popper's physics by Asher Peres suggests, Popper's grasp of 'science' was tenuous.[377] And yet, *Daubert* (and the law) embrace him. It is time to reformulate the legal view of science, and especially 'good science,' based on a scientist's view and actual practice:

> **What is 'good science'?**
> **'Good science' is objective knowledge (pertaining to the finite world or universe) produced via experiments or observations generating trustworthy (valid) and accurate (reliable) results.** The first requirement requires a qualitative assessment that the results both answer the hypothetical proposition and conforms to previously validated scientific thought. The second requires is a quantitative assessment that the results are 'good enough.'

VI. CONCLUSION: SUMMARY AND FURTHER RESEARCH

Popper's notions of falsifiability and falsification and his emphasis on disproof, it is submitted, are inapplicable to the science of the courtroom. Thus this paper establishes that:

Popper's ideas were conceived in response to, and provoked by, personal dilemmas in quantum physics and cosmology. They were derived from and relate to quantum physics, and have no relevance to biology, chemistry and Newtonian physics, the 'stuff' of litigation. Per Popper: There is no truth in science, except in the temporary sense. Evidence of disproof is not reliable, although reliability is a key requirement of *Daubert*. Some notions we see as scientific, Popper classifies as 'metaphysical' and would be outside the aegis of legal admissibility. Not all *bona fide* scientific statements can be falsified. Some statements about religion can be falsified, debunking Popper's notion that falsifiability differentiates between science and metaphysics. Some true scientific statements can be falsified, leading to false knowledge, or as Popper calls it 'nescience.' Popper's falsification does not tolerate dual or multi-causation. The legal burden of proof favors the status quo (the default position is that the defendant wins); the scientific burden of proof favors the proponent; i.e., in the event the evidence is in equipoise regarding the null hypothesis, the presumption is that the reverse proposition (the actual hypothesis) prevails. The odds of prevailing favor the defendant in law, the proponent under Popper.

According to *Daubert*, to qualify as "scientific knowledge," an inference or

[377] Asher Peres, *Karl Popper and the Copenhagen Interpretation,* STUD. HISTORY PHILOS. MODERN PHYSICS 33 (2002) 23, arXiv:quant-ph/9910078.

assertion must be derived by the scientific method. Proposed testimony must be supported by appropriate validation—i.e., "good grounds," based on what is known. In short, the requirement that an expert's testimony pertain to "scientific knowledge" establishes a standard of evidentiary reliability.

Having now removed the taint of Popper's falsifiability and falsification, and recrafted a scientifically viable definition of 'science' and 'good science,' it is now possible to examine the requirement of conformity to the scientific method in order to fully devise a new gatekeeper paradigm.

APPENDIX

Jonathan Bing by Beatrice Curtis Brown[378]

Poor old Jonathan Bing,
went out in his carriage to visit the King,
but, everyone pointed and said 'look at that!
Jonathan Bing has forgotten his hat!'
(He'd forgotten his hat!)

Poor old Jonathan Bing,
went home and put on a new hat for the King,
but up by the Palace a soldier said, 'Hi!,
you can't see the King; you've forgotten your tie!'
(He'd forgotten his tie!)

Poor old Jonathan Bing,
went and put on a beautiful tie for the King,
but when he arrived, an Archbishop said,
'Ho!
You can't come to court in pajamas,
you know!'

Poor old Jonathan Bing
Went home and addressed a short note to the King:
"If you please will excuse me, I won't come to tea;
For home's the best place for all people like me."

[378] *See* BROWN, *supra* note 2, at 10.