Beyond the Polemic Against Junk Science: Navigating the Oceans that Divide Science and Law with Justice Breyer at the Helm

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INTRODUCTION

> *After all, the dangers that face the world, every one of them, can be traced back to science. The salvations that may preserve the world, every one of them, will be traced back to science.*[1]

If we can assume that "the reason that judges (and lawyers) are in the courtroom is because they did not want to study science and they had no interest in science and majored in something that had nothing to do with it,"[2] those of us who study and practice law today have a serious problem. As Justice Stephen Breyer has repeatedly warned, "[t]he legal disputes before us increasingly involve the principles and tools of science."[3] Thus, it is important that judges, lawyers, and legal scholars understand basic scientific principles

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[1] Leslie Alan Horvitz, *The Quotable Scientist* 159 (McGraw-Hill 2000) (quoting Isaac Asimov).

[2] *Judicial Panel Discussion on Science and the Law*, 25 Conn. L. Rev. 1127, 1128 (1993) (quoting Professor Steven J. Grossman). Although this article is limited in scope to the federal courts, it may also prove useful to those practicing in jurisdictions that have adopted the *Daubert/Kumho* test for scientific admissibility. The issue of scientific evidence in the state courts has been extensively addressed elsewhere. *See e.g.* Paul Gianelli, *Forensic Science: Daubert in the States,* 34 Crim. L. Bull. 154 (1998).

[3] Justice Stephen Breyer, *Introduction*, in *Reference Manual on Scientific Evidence* 2 (Federal Judicial Center 2000). The Reference Manual on Scientific Evidence was first published by the Federal Judicial Center in 1994 as a response to the Supreme Court's decision in *Daubert v. Merrell Dow Pharms., Inc.*, 509 U.S. 579 (1993). Although it provides a wide range of helpful and practical information on science and law, the Reference Manual on Scientific Evidence has been criticized as defense-oriented by various plaintiffs' organizations. Joseph T. Walsh, *Keeping the Gate: The Evolving Role of the Judiciary in Admitting Scientific Evidence,* 83 Judicature 140, 141 (1999) (noting also the belief that the manual misinterprets *Daubert*'s teaching).

and methodologies. According to Justice Breyer, the potential effects of the misuse of science "matter[] not just to the litigants, but also to the general public—those who live in our technologically complex society and whom the law must serve."[4]

The disjuncture between science and law became a significant practical, rather than theoretical, problem in 1993 when the Supreme Court decided *Daubert v. Merrell Dow Pharmaceuticals, Inc.*[5] *Daubert* was a radical break from a tradition of judicial deference to scientific norms and conventions on questions of the admissibility of scientific evidence. The Court called upon the federal judiciary to slam the gate on all scientific evidence that is not "'scientific knowledge' . . . derived from the scientific method."[6] Since 1993, the Supreme Court has issued three opinions clarifying *Daubert*,[7] and countless judges and legal commentators have wrestled with the application of *Daubert's* judicial "gatekeeping" requirement.[8] Although the Court intended *Daubert* and its progeny to enhance the developing relationship between science and law, this promise of *Daubert* has not yet been realized. Instead, *Daubert* has imposed a foreign and unwieldy burden on judges who must resolve questions of scientific admissibility,[9] lawyers who must master the scientific theories of expert witnesses, and legal and scientific scholars searching for meaning and

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4 Breyer, *supra* n. 3, at 2.

5 509 U.S. 579 (1993). *See also infra* Part I.A(1) (discussing the *Daubert* case).

6 *Id.* at 590.

7 Legal scholars normally refer to the "*Daubert* trilogy" as including *Daubert, Gen. Electric Co. v. Joiner*, 522 U.S. 136 (1997), and *Kumho Tire Co. v. Carmichael*, 526 U.S. 137 (1999). For reasons discussed below, however, a thorough analysis of Supreme Court doctrine on science and law should also include *United States v. Scheffer*, 523 U.S. 303 (1998). *See infra* Part I.A(2).

8 In light of the general and sometimes confusing nature of *Daubert*, "[a]ttempting to understand the application of Daubert by trial and appellate courts in the years that immediately followed can be frustrating. Daubert is a very incomplete case, if not a very bad decision. . . . What resulted was a series of conflicting and confusing opinions." Michael H. Graham, *The Expert Witness Predicament: Determining "Reliable" Under the Gatekeeping Test of Daubert, Kumho, and Proposed Amended Rule 702 of the Federal Rules of Evidence*, 54 U. Miami L. Rev. 317, 321 (2000).

9 Many judges have expressed discomfort with the process of reviewing scientific methodologies and techniques and believe that *Daubert* and its progeny have made their lives more difficult. *See e.g.* Scott C. Andre, *Weird Science: Problems with the U.S. Supreme Court's New Evidentiary Standard for Expert Testimony and Oregon Case Law as a Possible Solution*, 73 Or. L. Rev. 691, 692 (1994) (stating that *Daubert* places too heavy a burden on judges to make qualitative determinations about science); Jennifer Laser, *Inconsistent Gatekeeping and Federal Courts: Application of Daubert v. Merrell Dow Pharm., Inc. to Nonscientific Expert Testimony*, 30 Loyola L.A. L. Rev. 1379, 1380 (1997) (observing that the application *Daubert* rule has split the circuits); Rory Sherman, *"Junk Science" Rule Used Broadly: Judges Learn Daubert*, Natl. L. J. 3, 28 (Oct. 4, 1993) (describing judicial discomfort with the *Daubert* decision and quoting U.S. District Judge Jack B. Weinstein as saying "[a]fter all, we're not scientists").

direction.

In the midst of this maelstrom, one year after the *Daubert* decision, Justice Stephen Breyer joined the Court and has taken the helm. His most substantive contribution to date, the majority opinion in *Kumho Tire Co.. v. Carmichael*,[10] offered future courts a subtly transformed analytic tool for assessing scientific, technical and other specialized evidence. Justice Breyer's public statements and writings further demonstrate his view that good science and good law are increasingly interdependent. In a recent speech before members of the American Association for the Advancement of Science, he described the relationship between science and law as follows:

> The fact of interdependence is evident. You find it obvious that the practice of science depends upon sound law—law that, at a minimum, provides support for science by offering the scientist breathing space, within which he or she may search freely for the truth upon which all knowledge depends. It may be less obvious to you, but it is equally true, that the law itself increasingly needs access to sound science.... [A]s society becomes more dependent for its well being upon scientifically complex technology, we find that this technology increasingly underlies legal issues of importance to all of us.[11]

If justice requires valid science, we must avoid and denounce efforts to manipulate science within the legal system.

The legitimate incorporation of science into law begins by separating the notion of scientific validity from the idea that a particular scientific theory serves some other goal. It is therefore irrelevant to the validity of a scientific theory that it helps our client, jibes with our social or political inclinations, resonates with the public, benefits the legislature, or proves useful to the courts.[12] Although it may be true that "many people choose scientific beliefs the same way they choose to be Methodists, or Democrats, or Chicago Cubs

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[10] 526 U.S. 137 (1999).

[11] Associate Justice Stephen J. Breyer, Speech, "The Interdependence of Science and Law" (Association for the Advancement of Science Annual Meeting and Science Innovation Exposition, Feb 16, 1998) <http://aaas.org/meetings/1998/breyer98.htm>. For example, we have seen a rapid increase in the use of medical expert testimony in the context of cases involving DNA analysis. *See e.g.* Jonathan J. Koehler, *Proving the Case: The Science of DNA: On Conveying the Probative Value of DNA Evidence: Frequencies, Likelihood Ratios, and Error Rates*, 67 U. Colo. L. Rev. 859 (1996) (noting the advent of the presentation of DNA evidence in the courtroom).

[12] In a previous article I have explored the problems created by laws and doctrine designed to satisfy community hatred of those charged with sex offenses. *See generally* Joëlle Anne Moreno, *"Whoever Fights Monsters Should See to It That in the Process He Does Not Become a Monster": Hunting the Sexual Predator with Silver Bullets—Federal Rules of Evidence 413-415—and a Stake Through the Heart—Kansas v. Hendricks*, 49 Fla. L. Rev. 505 (1997).

fans . . . by how well it agrees with the way they want the world to be,"[13] legal scholars and practitioners must strive to make unbiased assessments of scientific validity.[14] As a distinguished group of professors and scholars recently wrote in an amicus brief for the Supreme Court in *Browner v. American Trucking Associations*,[15] "[s]cience describes, it does not prescribe."[16] Although we may understand that science, in theory, should be value-neutral, problems arise "[i]n an adversarial system, where even facts come in two versions, [and] it's easy to view science as just another form of spin."[17]

Any genuine effort to improve our ability to understand and use science must also transcend the popular academic sport of denouncing "junk science."[18] Through a series of well-publicized books and articles, legal

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[13] Robert Park, *Voodoo Science: The Road from Foolishness to Fraud* viii-ix (Oxford U. Press 2000).

[14] Of course, objectivity in the courtroom depends on objectivity in the laboratory. Judicial decisions evaluating scientific validity can be contaminated when the scientists themselves are engaged in the business of advancing particular drug products or pet social or political agendas. A scientist's personal or pecuniary interest in the outcome of an experiment can taint the resulting data and, if exposed, his conclusions will not contribute to the development of scientific knowledge. *See e.g.* Kurt Eichenwald & Gina Kolata, *Hidden Interest— A Special Report: When Physicians Double as Entrepreneurs,* 149 N. Y. Times A1 (Nov. 30, 1999) (describing how financial links between interventional cardiologists and medical device companies have corrupted the traditions of objective medical research and review).

[15] Br. of Amici Curiae in Support of Resps., at *5, *Browner v. American Trucking Assns. Inc.*, (No. 99-1257), 2000 WL 1298950 (explaining that "science seeks to supply verifiable descriptions of, and explanations about, what *is*, rather than imposing judgments about what *should be*") (emphasis added).

[16] *Id.*

[17] Atul Gawande, *Under Suspicion,* New Yorker 53 (Jan. 8, 2001).

[18] According to Peter Huber:

> Junk science is the mirror image of real science, with much of the same form but none of the same substance. There is the astronomer, on the one hand, and the astrologist, on the other . . . . [Junk science] is a hodgepodge of biased data, spurious inference, and logical legerdemain, patched together by researchers whose enthusiasm for discovery and diagnosis far outstrips their skill. It is a catalog of every conceivable kind of error: data dredging, wishful thinking, truculent dogmatism, and, now and then, outright fraud.

Peter W. Huber, *Galileo's Revenge: Junk Science in the Courtroom* 2-3 (BasicBooks 1991). Although Peter Huber is widely credited with coining the term "junk science," ironically *Galileo's Revenge* has sometimes been dismissed as "junk social science" for its reliance on anecdotes and other factual inaccuracies. *See e.g.* Jeff L. Lewin, *Calabresi's Revenge: Junk Science in the Work of Peter Huber,* 21 Hofstra L. Rev. 183 (1992) (criticizing both Huber's legal and scientific analysis). For other recent works addressing the "junk science" phenomenon from various perspectives, see, e.g., Park, *supra* n. 13; Michael Shermer, *Why People Believe Weird Things: Pseudoscience, Superstition, and Other Confusions of Our Time* (W.H. Freeman & Co. 1999) (distinguishing science from "pseudoscience"); Marcia scholars and scientists have focused academic discourse, and public outrage, on the "junk scientist"—the expert witness who "seeks to present grossly fallacious interpretations of scientific data or opinions that are not supported by scientific evidence."[19] Diatribes against the junk scientist are replete with fantastic examples of the vast influence of bogus science on the American judicial system. In addition, concern about junk science in our social and political dialogues has influenced lawmakers and the courts.[20] These academic and public debates have been further fueled by the advent of well-publicized mass tort litigation. For example,

> [o]ver the past 20 years, the public's attention has been caught in rapid succession by asbestos, diethylstilbestrol (DES), Bendectin, the Dalkon shield, Agent Orange, Alar-treated apples, radon, and electromagnetic fields, among other real or alleged health hazards. Each engendered a mix of fear, recriminations, and denials. There were also mass lawsuits, Congressional hearings, and demands for tighter government regulation. The scientific evidence was highly variable. . . . [However,] [t]he strength of the evidence seemed irrelevant to the public debate. Risks for which there was little evidence were taken as seriously as those for which there was good evidence, and small risks received as much attention as large ones.[21]

The problem of science that is misused or misunderstood by judges, lawyers, and jurors is real.[22] The "junk science" debate, however, ignores the

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Angell, *Science on Trial: The Clash of Medical Evidence and the Law in the Breast Implant Case* (W.W. Norton & Co. 1996) (noting the effects of "pseudoscience" on both the popular mind and the courts).

[19] Kenneth R. Foster & Peter W. Huber, *Judging Science: Scientific Knowledge and the Federal Courts* 17 (MIT Press 1999).

[20] *See* Breyer, *supra* n. 3, at 4 (citing *Galileo's Revenge* and explaining that "[t]he law must seek decisions that fall within the boundaries of scientifically sound knowledge"); *see also Daubert*, 509 U.S. at 593 (1993) ("[S]ubmission to the scrutiny of the scientific community . . . increases the likelihood that substantive flaws in methodology will be detected.").

[21] Marcia Angell, Evaluating the Health Risks of Breast Implants: The Interplay of Medical Science, the Law, and Public Opinion. 334 New Eng. J. Med. 1513,1517 (1996); *see also* Joseph Sanders, *Scientifically Complex Cases, Trial by Jury, and the Erosion of Adversarial Process*, 48 DePaul L. Rev. 355, 359 (1998). Sanders states:

> Given the limited evidence now available, one cannot conclude with certainty that the "mean difficulty" of expert testimony in civil cases has gone up. What is more certain is that the absolute number of "hard" cases has increased. Moreover, many of these cases have two other attributes that have magnified their significance. First, many have involved mass torts . . . . Second, and not unrelated, many of the cases have been tried in federal courts.

Id.

[22] Although some bad science results from the use of unethical professional expert witnesses, much of the science deemed too "bad" for legal use has perfectly ethical bases.

range of scientific mistakes and misunderstandings that permeate the law. Junk science is neither the source nor the scope of the problem among scientists, legal scholars, and practitioners. Instead, the junk science debate is merely a byproduct of an adversarial system that too often fails to seek practical methods to enhance communication and collaboration with disciplines outside the law.[23]

This Article offers a specific response to Justice Breyer's charge that judges "must aim for decisions that, roughly speaking, approximately reflect the scientific 'state of the art.'"[24] To that end, the Article addresses the impediments to developing consistent legal standards governing the admissibility of scientific evidence by offering two analytic tools, one legal and one scientific. This Article then demonstrates how these tools can be used to evaluate scientific evidence.

Part I presents the first tool: a new interpretation of *Kumho* positing that the *Daubert* admissibility test has been significantly altered by Justice Breyer to place the exploration of scientific validity squarely in the context of a relevance inquiry. The first section begins the case and rule analysis by tracing the development of the admissibility standard from *Daubert* through *Kumho*. The second section explores Justice Breyer's specific response to the problems created by *Daubert* in *Kumho Tire Company v. Carmichael*. The third section examines how *Kumho* is emblematic of Justice Breyer's personal jurisprudence and is intended as a model of proper judicial inquiry into scientific admissibility.

Part II of the Article provides the second tool: a hands-on presentation of basic scientific terminology, methodology, and statistical concepts to be used in conjunction with the new test. The first section aims to develop a scientific lexicon for the law by demonstrating that a new test alone cannot meet Justice Breyer's charge. In response, this section offers guidance for interpreting the critical scientific terminology that has been imported into the current legal standard by the Supreme Court. The second section provides practical information intended to improve our comprehension of basic scientific methodology. The third section identifies and explains certain fundamental statistical concepts essential to our comprehension of all empirical data.

Part III of the Article integrates both tools to demonstrate our legal limits by showing how an improved admissibility standard and enhanced scientific

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> The high regard for science in the popular imagination undoubtedly arises from the fact that ordinary textbook science is usually true. But much of the science that the layperson encounters in the mass media . . . doesn't come from the textbooks. It is, at best, frontier science—the scientific equivalent of an experimental aircraft that may or may not someday be robust enough to fly.

Foster & Huber, *supra* n. 19, at 159.

[23] *Id.* at 17 ("Junk science is a legal problem, not a scientific one. It is cultivated by the adversarial nature of the legal proceedings, and it depends on the difficulty many people have in evaluating technical arguments.").

[24] Breyer, *supra* n. 11.

sophistication will help us identify scientific evidence that is so technical or complex that accurate evaluation requires outside assistance. Using these tools, we can begin crafting creative interdisciplinary solutions.

I. HONING THE LEGAL TOOLS

A. *The Supreme Court Develops an Admissibility Test for Scientific Evidence*

1. *Daubert* Creates a New Role for the Court

The *Daubert* plaintiffs were two children born with serious birth defects allegedly caused when their mothers took the prescription antinausea medication Bendectin while pregnant.[25] At trial, the plaintiffs presented eight scientific experts who testified to a causal connection between Bendectin and the childrens' birth defects. These experts based their conclusion on *in vitro* (test tube) and *in vivo* (live animal) studies that found a causal link, pharmacological studies that showed similarities in the chemical structure of Bendectin and other known teratogens,[26] and the experts' reanalysis of published human epidemiological studies.[27] The defendant's epidemiologist testified that based on a review of all of the relevant epidemiological literature, not one scientific study had found that Bendectin was a human teratogen.[28]

The district court granted summary judgment for the defendant, holding that the scientific expert evidence offered by the plaintiffs did not satisfy the *Frye*[29]

[25] Bendectin was introduced in 1957 by Merrell Dow Pharmaceuticals as a remedy for morning sickness, and it was eventually used by more than 33 million women. Foster & Huber, *supra* n. 19, at 2. The *Daubert* case should be understood in its historical context as one of more than 1,900 Bendectin cases filed from 1977 to 1988. Jay P. Kesan, *An Autopsy of Scientific Evidence in a Post Daubert World*, 84 Geo. L. J. 1985, 2004-05 (1996) (reasoning that Merrell Dow kept winning at trial and on appeal because the plaintiffs' experts had not sought formal scientific review for their Bendectin research results). For an extensive review of the medical literature discussing Bendectin, see Robert L. Brent, *Bendectin: Review of the Medical Literature of a Comprehensively Studied Human Nonteratogen and the Most Prevalent Tortogen-Litigen*, in 9 Reproductive Toxicology 337 (1995).

[26] A "teratogen" is a substance capable of causing malformations in fetuses. *Daubert*, 509 U.S. at 582 (1993).

[27] *Id.* at 583.

[28] *Id.* at 582.

[29] The courts first recognized a special rule for the admissibility of scientific evidence in the 1923 case of *Frye v. United States*, 293 F. 1013 (D.C. Cir. 1923). In *Frye*, the defense attempted to admit the results of a systolic blood pressure detection test as exculpatory evidence, and it presented scientific testimony to support the belief that a person's blood pressure will rise when he or she is not telling the truth. The D.C. Court of Appeals upheld the trial court's refusal to admit the defendant's scientific evidence on the ground that the systolic blood pressure deception test had not gained "general acceptance" as a method of assessing truth telling. *Id.* at 1014. In a frequently-quoted passage, the *Frye* court held that

test because it was not generally accepted in the field of human epidemiology.[30] In a two-page decision by Judge Alex Kozinski, the Ninth Circuit affirmed the district court's grant of summary judgment and upheld the application of the *Frye* test.[31]

When *Daubert* reached the Supreme Court, the threshold question was whether the *Frye* "general acceptance test" for the admissibility of scientific evidence could logically coexist with the more recently enacted Federal Rules of Evidence.[32] Justice Blackmun, with the backing of the entire Court, quickly concluded that the *Frye* test, which used "general acceptance" as a surrogate for reliability, had not survived the adoption of Rule 702 of the Federal Rules of Evidence.[33] Although the Court could have remanded the case to the Ninth

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> when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs.

Id. Thus, under *Frye*, courts played a limited role in the qualitative assessment of scientific expert testimony. They only needed to identify the relevant scientific discipline and then, if the theory or technique was "generally accepted" within that community, the testimony had to be admitted. The "general acceptance" standard did not die with *Frye*, as it has been incorporated into the *Daubert* analysis. *See Daubert*, 509 U.S. at 594 ("Widespread acceptance can be an important factor in ruling particular evidence admissible."); *see also Standards and Procedures for Determining the Admissibility of Expert Evidence After Daubert*, 157 F.R.D. 571, 572 (1994) (describing how the "general acceptance" standard allowed judges to defer to the scientific community and avoid the difficulties of evaluating confusing and technical information outside the court's area of expertise).

30 According to the District Court, the plaintiffs' experts' non-epidemiological evidence was inadmissible in light of the large amount of epidemiological evidence available. *See Daubert v. Merrell Dow Pharms. Inc.*, 727 F. Supp. 570, 572-75 (S.D. Cal. 1989), *rev'd*, 509 U.S. 579 (1992). The plaintiffs' epidemiological evidence was found unpersuasive because it reanalyzed existing data and had not been published or subjected to peer review. *Id.*

31 Judge Kozinski explained that three circuits that had considered similar cases had found the plaintiffs' experts' studies "particularly problematic in light of the massive weight of the original published studies supporting the defendant's position, all of which had undergone full scrutiny from the scientific community." *Daubert v. Merrell Dow Pharm., Inc.*, 951 F.2d 1128, 1129-30 (9th Cir. 1991).

32 The parties in *Daubert* advanced conflicting arguments about which rule applied if the Court abandoned the *Frye* test. The plaintiffs argued that the Federal Rules of Evidence should be interpreted to admit all relevant testimony proffered by a qualified expert. The defendant, Merrell Dow, argued that any new rule fashioned by the Court must evaluate the reliability of the conclusions proffered by the scientific expert. *See* Michael H. Gottesman, *The Randolph W. Thrower Symposium: Scientific and Technical Evidence: Admissibility of Expert Testimony After Daubert: The "Prestige" Factor*, 43 Emory L.J. 867, 869 (1994).

33 According to the Court, "a rigid 'general acceptance' requirement would be at odds

Circuit without further comment, Justice Blackmun instead created a new "gatekeeping" role for the judge confronted with proffered scientific evidence.[34] *Daubert* is based on the assumption that the trial judge can and should screen scientific evidence so that the jury will not hear evidence unless it is both reliable and relevant. As one observer has noted:

> *Daubert's* underlying rationale is a sound one: lay jurors should not be exposed to unfiltered scientific or technical testimony that may adversely influence their findings of fact. But this rationale is based on two underlying assumptions: (1) that the trial judge is more knowledgeable in assessing complex scientific testimony than is the average lay juror, and (2) that each judge brings to the specific task of gatekeeping a general attitude or philosophy concerning the level of scrutiny appropriate for scientific gatekeepers.[35]

The *Daubert* Court required federal trial judges first to determine if an expert's testimony is "scientific knowledge" before opening the gate to admit the evidence at trial.[36] Thus, "scientific knowledge"[37] replaced "general

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with the 'liberal thrust' of the Federal Rules [of Evidence] and their 'general approach of relaxing the traditional barriers to 'opinion' testimony." *Daubert*, 509 U.S. at 588 (citations omitted). In addition, by 1993, the Court was aware of the widespread perception that the *Frye* test was used to exclude reliable scientific expert testimony that related to novel or developing scientific theories or techniques. *See e.g.* Kristina L. Needham, Student Author, *Questioning the Admissibility of Nonscientific Testimony After Daubert: The Need for Increased Judicial Gatekeeping to Ensure the Reliability of All Expert Testimony*, 25 Fordham Urb. L. J. 541, 544-545 (1998) (noting that the "*Frye* test was overly conservative . . . because expert testimony based upon a newly developed methodology was rendered inadmissible if it was not generally accepted"); Graham, *supra* n. 8, at 322 (noting that, as a practical matter, *Frye* was applied only to new or novel forensic evidence offered by the government in criminal cases).

[34] Justice Blackmun was joined by Justices Kennedy, O'Connor, Scalia, Souter, Thomas, and White in his creation of the judicial gatekeeper, while Justices Rehnquist and Stevens dissented. It should be noted that the immediate response among the federal judiciary to *Daubert* was generally negative. In the words of one commentator,

> [m]any federal judges believe Daubert has made their lives more difficult. They are going to have to give a more reasoned statement about why they are letting in evidence. They can't do it on a rubber stamp basis the way that some of them did it in the past.

Sherman, *supra* n. 9, at 3. *See also* sources cited *supra* n. 9 (describing the judicial discomfort that followed *Daubert*).

[35] Walsh, *supra* n. 3, at 1.

[36] *See Daubert* 509 U.S. at 590 (stating that "the subject of an experts' testimony must be 'scientific knowledge'").

[37] "Scientific knowledge" is defined only vaguely by the *Daubert* Court as "an inference or assertion . . . derived by the scientific method." *Id.* at 590. Justice Blackmun defines "scientific method" as scientific knowledge that "implies a grounding in the methods and procedures of science." *Id.* at 589-90. In addition, the Court notes that "[s]cientific 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

acceptance" as the proper standard.

According to Justice Blackmun, judges must decide whether to admit or exclude scientific evidence based on the scientific reliability of the proffered testimony and its relevance.[38] The Court defined the judicial inquiry as "flexible," noting that "[i]ts overarching subject is the scientific validity—and thus the evidentiary relevance and reliability—of the principles that underlie a proposed submission."[39] The judge's focus, according to the Court, "must be solely on principles and methodology, not on the conclusions they generate."[40]

To assist judges who would now need to distinguish between reliable and unreliable scientific evidence, Justice Blackmun outlined four "flexible guidelines": (1) testability; (2) peer review and publication; (3) error rate; and (4) general acceptance.[41] Under the first guideline, a scientific theory must be testable through scientific methodology.[42] Scientific knowledge is based upon generating hypotheses and testing them to see if they can be falsified, or proven untrue; indeed, this methodology is what distinguishes science from other fields of human inquiry.[43] Under the second guideline, the scientific

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inquiry." *Id.* at 593 (citations omitted).

[38] *See Daubert*, 509 U.S. at 589 (explaining that the trial judge must ensure that all scientific testimony or admitted evidence is not only relevant but reliable).

[39] *Id.* at 594-95.

[40] *Id.* at 595. Four years after *Daubert*, the Court acknowledged that the task of separating principles, methodology, and conclusions was not as simple as they had previously assumed. *See Gen. Electric Co. v. Joiner*, 522 U.S. 136, 146 (1997) (concluding that in science "conclusions and methodology are not entirely distinct from one another").

[41] *Daubert*, 509 U.S. at 593-94.

[42] *Id.* at 593. Testability is critical to the Court's analysis. However, the Court fails to provide future judges with any criteria or standards that might be used by courts to assess the testability of a particular scientific theory. Instead, Blackmun combines the concepts of testability and peer review, noting that "submission to the scrutiny of the scientific community is a component of 'good science,' in part because it increases the likelihood that substantive flaws in methodology will be detected." *Id.*

[43] *Id.* To support this criterion, the *Daubert* Court specifically referenced the highly influential work of scientific theorist Karl Popper. *Id* at 593-94 (quoting Popper's observation that "the criterion of the scientific status of a theory is its falsifiability, or refutability, or testability"). Popper believed that scientific propositions must be framed so that contradiction by other scientists is possible. Thus, scientific theories that have withstood the criticism of other scientists should be adjudged as more reliable than those that cannot be tested. *See* Foster & Huber, *supra* n. 19, at 19 (discussing Popper's view of scientific falsifiability); *see also* Gottesman, *supra* n. 32, at 876.

> The 'testability' notion comes from the demands of pure sciences, such as physics or astronomy. In these fields, scientists are seeking enduring truths, and will settle for nothing less than certainty. . . . The 'error rate' notion comes at the other end of the spectrum, where explorations are so mechanical that it is actually possible to identify whether there is a correlation between the methodology's findings and the observable world.

Gottesman, *supra* n. 32, at 876.

theory or technique must have been subjected to peer review and publication to allow other scientists to detect possible substantive flaws in the methodology.[44] The third guideline focuses the judge on the known or potential rate of error of a particular scientific technique[45] and the "existence and maintenance of standards controlling the technique's operation."[46] Finally, the *Daubert* Court resurrected the *Frye* standard by stating that "[w]idespread acceptance can be an important factor in ruling particular evidence admissible, and 'a known technique which has been able to attract only minimal support within the community'... may properly be viewed with skepticism."[47]

Daubert effected a radical change in doctrine and practice. In the years since *Daubert*, however, lawyers, judges, and legal scholars have paid little attention to the inherently problematic structure of the *Daubert* test itself. The two-part *Daubert* test requires judges *first* to determine the general validity of any proffered scientific expert testimony. "This first prong of the Court's analysis thus requires judges to critique scientific evidence and separate the wheat of valid scientific methodology from the chaff of chicanery."[48] According to the Court, assessing general scientific reliability must precede a judicial determination of whether the evidence "fits" the facts at issue.[49] Requiring judges to engage in a broad inquiry into scientific reliability before they determine whether proffered scientific evidence "fits" the facts at hand can distort the admissibility decision by appearing to expand the role of the

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[44] *See Daubert*, 509 U.S. at 593 (stating that the "submission to the scrutiny of the scientific community is a component of 'good science,' in part because it increases the likelihood that substantive flaws in methodology will be detected.").

[45] Once again the *Daubert* Court failed to provide any specific criteria for a judge confronting the task of assessing the "known or potential error rates" of a particular scientific methodology. *See id.* at 594 (stating merely that "the Court ordinarily should consider the known or potential rate of error"). The Court does not explain the concept of error rate even at the most basic level (i.e., false positives versus false negatives). These difficulties can be compounded by the fact that different scientific disciplines frequently have different methods of estimating error rates. *See* Erica Beecher-Monas, *A Ray of Light for Judges Blinded by Science: Triers of Science and Intellectual Due Process*, 33 Ga. L. Rev. 1047, 1054 (1999) (describing the variance in error calculation among different scientific disciplines).

[46] *Daubert*, 509 U.S. at 594.

[47] *Id.* at 594; *see also* Daniel J. Capra, *The Daubert Puzzle*, 32 Ga. L. Rev. 699, 705 (1998) (explaining that the *Daubert* Court's continued reliance on general acceptance and peer review assures that scientific evidence that would have satisfied *Frye* will be deemed admissible while scientific evidence that attracts limited support from the relevant scientific community is likely to be deemed inadmissible (citations omitted)).

[48] Erica Beecher-Monas, *Blinded by Science: How Judges Avoid the Science in Scientific Evidence*, 71 Temp. L. Rev. 55, 62 (1998) (discussing the preliminary assessment requirement of the *Daubert* test).

[49] *Daubert*, 509 U.S. at 592-93 (explaining that the judge must determine the scientific validity of an expert witness's testimony before applying the reasoning and methodology to the case at hand).

court beyond consideration of relevant evidence. This is particularly problematic when a judge must focus on the unfamiliar world of science. Despite having been immediately criticized for imposing an unwieldy burden on the federal courts, the *Daubert* test remained essentially unchanged for the next five years.

2. *United States v. Scheffer*: The Bastard of *Daubert's* Progeny

a. *Defining the Outer Limits of Science*

Although normally excluded from academic discussions of Supreme Court doctrine on science and law, *U.S. v. Scheffer*[50] reveals the Court's conception of the boundaries of legitimate science. In 1992, Edward Scheffer was working as an informant for the Air Force Office of Special Investigations.("OSI").[51] As a condition of his employment, Scheffer was required to provide urine samples and submit to polygraph examinations.[52] On April 17, 1992, OSI requested a urine sample; three days later Scheffer submitted to a polygraph examination.[53] According to the polygraph examiner, "the test 'indicated no deception' when Scheffer denied using drugs since joining the Air Force."[54] Scheffer was arrested on May 13, 1992, for being absent without leave, and subsequently, his April 17, 1992, urine sample tested positive for methamphetamine.[55]

Scheffer was tried by general court martial. At this proceeding, he was barred from introducing the results of his polygraph examination by Military Rule of Evidence 707 ("MRE 707"), which contains a per se exclusion of polygraph evidence in military court martial proceedings.[56] Basing his defense on a theory of innocent ingestion, Scheffer denied having knowingly ingested the methamphetamine while working for OSI.[57] On cross-examination, the prosecutor attempted to impeach Scheffer with prior inconsistent statements.[58] In closing argument the government stated, "He lies. He is a liar. He lies at every opportunity he gets and he has no credibility."[59] He was convicted and

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[50] 523 U.S. 303, 312 (1998).

[51] *Id.* at 305 (1998).

[52] *See id.* (stating that Scheffer's supervisor informed him that he would periodically be tested).

[53] *See id.* at 306.

[54] *See id.*

[55] *See id.* at 306-07.

[56] *See id.* at 306.

[57] *See id* (providing the relevant portion of MRE 707).

[58] *See id.* at 306 n.1

[59] *See id.* (explaining that Scheffer introduced the polygraph evidence to corroborate his belief that he had not ingested methamphetamine); *see also* Robin D. Barovick, *Between Rock and a Hard Place: Polygraph Prejudice Persists After Scheffer*, 47 Buff. L. Rev. 1533, 1547 n. 66 (1999) (noting that the government called Scheffer a liar or stated that his

sentenced to thirty months of confinement, a bad-conduct discharge, total forfeiture of all pay and allowances, and reduction to the lowest enlisted grade.[60] On appeal, the Court of Appeals for the Armed Forces found MRE 707 unconstitutional under the Sixth Amendment because it precluded a criminal defendant from admitting exculpatory evidence in response to a direct attack on his credibility.[61]

In the plurality opinion written by Justice Thomas, the Supreme Court reversed the Sixth Circuit and concluded that MRE 707 was constitutional.[62] Despite the fact that *Daubert* had received a flurry of attention only five years earlier, Justice Thomas essentially ignored *Daubert* and applied a *Frye*-type test.[63] The Court's reliance on *Frye* is demonstrated by the fact that the plurality opinion focused solely on the level of acceptance of polygraph test results in the scientific community.[64] According to Justice Thomas, a per se exclusion of polygraph results, without any effort by the judge to evaluate the scientific validity of the test, was acceptable because "the scientific community remains extremely polarized about the reliability of polygraph techniques."[65] The *Scheffer* Court concluded that science has boundaries, and since polygraph test results fall outside the boundaries of science, they can be excluded by the legislature without employing a *Daubert* analysis.

In a concurring opinion, drafted by Justice Kennedy and joined by Justices O'Connor, Ginsburg, and Breyer, these four justices agreed that the polygraph technique was unreliable and that per se exclusion of a scientifically unreliable technique did not raise constitutional concerns.[66] However, Justice Kennedy specifically recognized the "tension" between the *Daubert* rule and the

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credibility was lacking twenty-one times during closing argument).

[60] *See Scheffer*, 523 U.S. at 307.

[61] *See U.S. v. Scheffer*, 44 M.J. 442, 445 (C.A.A.F. 1996) (holding that a per se exclusion of polygraph evidence violated the Sixth Amendment rights of an accused when offered to rebut an attack on credibility).

[62] *See Scheffer*, 523 U.S. at 309 ("[Rule 707 does not] implicate a sufficiently weighty interest of the defendant to raise a constitutional concern under our precedents.").

[63] *See id.* at 310.

[64] It seems particularly strange that *Daubert* was ignored when just the previous term, the Court reaffirmed *Daubert* and stated that the appropriate standard for the trial court's findings on the relevance and reliability of scientific evidence is abuse of discretion. *See generally Gen. Electric Co. v. Joiner*, 522 U.S. 136, 142 (1997) (reaffirming *Daubert* and discussing the role of the court in reviewing a trial judge's decision to allow expert testimony).

[65] *See Scheffer*, 523 U.S. at 309-10 (1998) (comparing studies that have found polygraph tests reliable against those declaring them unreliable).

[66] *Id.* at 318 (Kennedy, J., concurring) (The "good-faith disagreement among experts and courts on the subject of polygraph reliability counsels against our invalidating a *per se* exclusion of polygraph results. . . . I agree the rule of exclusion is not so arbitrary or disproportionate that it is unconstitutional.").

Scheffer holding.[67] Despite stating that "the rule of exclusion is not so arbitrary or disproportionate as to be unconstitutional," Justice Kennedy expressed several reservations about the decision, including the belief that a different case might have presented an even more compelling case for the admissibility of polygraph test results.[68]

b. *Scientific Evidence Offered by the Criminal Defendant*

In addition to marking the Court's delineation of the outer limits of legitimate science, *Scheffer* highlights the unique concerns that arise when a criminal defendant offers scientific evidence as exculpatory evidence. The *Scheffer* plurality held that "Rule 707 does not implicate any significant interest of the accused."[69] The Court reasoned that the fact that Scheffer had testified in his own defense barred him merely from introducing expert opinion testimony based on polygraph test results to establish his own credibility.[70] The constitutional implications of the per se exclusion of exculpatory evidence offered by a criminal were the focus of a vigorous dissent by Justice Stevens.

Justice Stevens's dissent emphasized the defendant's Sixth Amendment argument by citing numerous Supreme Court decisions describing the constitutional right to present a defense as fundamental to the due process of law. To support his dissent, Justice Stevens noted that the *Scheffer* plurality had ignored the Court's longstanding concern for "potential injustice produced by rules that exclude entire categories of relevant evidence that is potentially unreliable."[71] The question of whether enhanced constitutional concerns should alter a judge's assessment of scientific evidence offered by a criminal defendant has not been widely discussed.[72] At a forum on scientific evidence, Chief Justice Ellen A. Peters of the Connecticut Supreme Court characterized the issue from a judge's perspective. She explained that DNA testing, since it more reliably excludes suspects than it includes suspects, is more likely to be

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67 Justice Kennedy wrote:

> I doubt, though, that the rule of *per se* exclusion is wise, and some later case might present a more compelling case for introduction of the testimony than this one does. Though the considerable discretion given to the trial court in admitting or excluding scientific evidence is not a constitutional mandate, . . . there is some tension between [the Daubert] rule and our holding today.

Id.

68 *Id.*

69 *Id.* at 316-17 (noting that Scheffer, who was allowed to testify on his own behalf, was barred only from introducing expert testimony).

70 *See id.* at 317.

71 *Id.* at 327 (Stevens, J., dissenting).

72 *But see* Gottesman, *supra* n. 32, at 877 (suggesting that different burdens of proof for civil and criminal trials should affect the admissibility standard for scientific evidence). "The civil law requires that parties establish their points only by a preponderance of the evidence, and not beyond a reasonable doubt. The standards for admitting expert testimony must be calibrated to that proof standard." *Id.*

probative and useful when introduced by the defense than when offered by the State.[73] More recently, a commentator advocated the use of a conservative approach when faced with "new 'scientific' technology and theories that have not been generally accepted by the relevant scientific community—especially where the so-called expert is testifying against the defendant in a criminal case."[74]

The Reference Manual on Scientific Evidence specifically recognizes that judicial reluctance to provide expert assistance to indigent criminal defendants may complicate a *Daubert* analysis, especially when the prosecutor relies on a novel scientific theory or methodology.[75] Both the Federal Rules of Evidence and case law, however, provide blanket rules for all proponents of scientific evidence. Thus, the prevailing assumption is that "[t]he standard of [scientific] reliability, whatever it is, will be the same for criminal and civil cases, the same for injunctive cases (simply ordering a party to do or not to do something), and cases in which monetary compensation is sought."[76]

3. *General Electric Co. v. Joiner*: Refining the Role of the Court

In 1997, the Supreme Court granted certiorari in *General Electric Co. v. Joiner*[77] to resolve the question left open by *Daubert* of the appropriate standard for appellate review of a trial court's decision to admit or exclude scientific evidence. In *Joiner*, the plaintiff claimed that exposure to polychlorinated biphenyls ("PCBs") had caused his lung cancer.[78] To support his claim, the plaintiff offered four epidemiological studies that purportedly established a causal link between defendant's PCBs and plaintiff's cancer.[79] The district court reviewed the plaintiff's four studies and found that: (1) the first study did not conclude that PCB's had caused lung cancer among the workers they examined;[80] (2) the second study found that there was a slightly increased incidence of lung cancer among workers at a PCB plant, but that the increase was not statistically significant;[81] (3) the third study did not mention

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[73] *Judicial Panel Discussion on Science and the Law*, *supra* n. 2, at 1131-37 (quoting Chief Justice Ellen Peters) (discussing whether the same admissibility test is appropriate for both exculpatory and inculpatory evidence).

[74] Capra, *supra* n. 47, at 703 (arguing that scientists are better equipped to assess the reliability of expert testimony than are judges).

[75] *See generally Reference Manual on Scientific Evidence*, *supra* n. 3.

[76] Foster & Huber, *supra* n. 19, at 135 (noting that the Federal Rules of Evidence do not distinguish between different legal contexts).

[77] 522 U.S. 136 (1997).

[78] *See Joiner v. Gen. Elec. Co.*, 864 F. Supp. 1310, 1314 (N.D. Ga. 1994).

[79] *See id.* at 145.

[80] *See Joiner*, 522 U.S. 136, 145 (1997) (referring to the conclusions of the district court).

[81] *See id.*

PCB's;[82] and (4) the fourth study subjects had been exposed to numerous potential carcinogens.[83] After excluding all of plaintiff's scientific expert testimony, the district court granted summary judgment for the defendant. The Eleventh Circuit used a "stringent standard of review" to reverse the district court.[84]

The *Joiner* decision, authored by Chief Justice Rehnquist, held that abuse of discretion is the appropriate standard of review for all evidentiary rulings, including the exclusion of scientific expert testimony.[85] Accordingly, the Eleventh Circuit was reversed for applying the wrong standard. In *Joiner*, the Court also continued to expand our understanding of the proper admissibility standard, noting that scientific "conclusions and methodology are not entirely distinct from one another."[86] Finally, Justice Rehnquist cautioned judges attempting to apply the *Daubert* test that "nothing in either Daubert or the Federal Rules of Evidence requires a district court to admit opinion evidence that is connected to existing data only by the *ipse dixit* of the expert."[87] Judges applying *Joiner*, therefore, must now assess the scope of the "analytic gap between the data and the opinion proffered" to determine if there is a sufficiently close correlation for the evidence to be admitted.[88]

B. *Justice Breyer Creates a New Admissibility Test for Scientific, Technical, and Other Specialized Evidence*

Just one year after deciding *Joiner*, the Supreme Court granted certiorari in *Kumho Tire Co., Ltd. v. Carmichael* [89] to decide a question that had split the federal circuit courts. The debate centered on whether the *Daubert* test applied exclusively to "scientific" testimony or if it governed the admissibility of all expert testimony, including "technical" or "specialized" knowledge.[90]

1. *Kumho Tire Co. v. Carmichael* [91]

In 1993, the Carmichael family was involved in a highway accident after the right rear tire on their family minivan failed.[92] The undisputed cause of the

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[82] *See id.* at 146

[83] *See id.*

[84] *See id.* at 141-43.

[85] *See id.* at 143.

[86] *Id.* at 146.

[87] *See id.* at 145.

[88] *Id.* at 146.

[89] 526 U.S. 137 (1999).

[90] *See id.* at 147.

[91] 526 U.S. 137 (1999) (reasoning that the *Daubert* rule is not limited to scientific expert testimony because Federal Rule of Evidence 702 grants the district judge the discretionary authority to determine the reliability of even nonscientific expert testimony in light of the circumstances of the case).

[92] *Carmichael v. Samyang Tire, Inc.*, 923 F. Supp. 1514, 1516 (S.D. Ala. 1996) (stating

blowout was tire separation, which occurs when the tread of a tire separates from the inner tire carcass.[93] The Carmichaels subsequently filed suit against the tire manufacturer and its distributor.[94]

The Carmichaels hired George Edwards as an expert witness to testify about tire defects.[95] Edwards determined that, because the tire failure did not result from negligent maintenance by the Carmichaels, there must have been a defect in either the tire's design or its manufacture.[96] Edwards never testified, however, because he fell ill before the defendants could depose him. Dennis Carlson, one of his employees, replaced Edwards as the plaintiffs' expert.[97] Carlson held a master's degree in mechanical engineering and had spent ten years testing tires for Michelin Americas Research and Development.[98] He agreed with Edwards that a defect in the manufacturing of the tire, rather than in its maintenance, caused the accident.[99] During his deposition, Mr. Carlson opined that tire failure was caused by "poor or insufficient adhesion between the rubber, steel, and nylon components of the tire."[100] His methodology consisted of a four-part visual examination of the tire in which he looked for "(1) greater tread wear on the shoulder than in the center of the tire; (2) sidewall deterioration or discoloration; (3) abnormal bead grooving on the tire; and (4) rim flange impression,"[101] to determine if over-deflection caused the tire failure. Carlson found that two of these four conditions were present and concluded that a design and/or manufacturing defect was to blame, not over-deflection.[102] After deposing Carlson, the defendants moved to exclude his

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that the facts of the case were undisputed). All seven family members suffered injuries and one died. *Id.*

[93] *Id.* at 1519.

[94] *Id.* at 1517 (noting while the Carmichaels sued the manufacturer, Kumho, as well as two distributors, they could not produce evidence that established the actual distributor of the tire at issue).

[95] *Carmichael v. Samyang Tire, Inc.*, 131 F.3d 1433, 1434 (11th Cir. 1997), *rev'd sub nom. Kumho Tire Co. v. Carmichael*, 526 U.S. 137 (1999).

[96] *Id.* ("Edwards concluded that a defect in either the tire's design or its manufacture caused the blowout.").

[97] *Id.*

[98] *Id.* at 1434 n. 2.

[99] According to Carlson, the tire separation was caused by either "over deflection" or a defect in the manufacturing process. *Carmichael*, 923 F. Supp. at 1519. Over deflection results from either under-inflation of the tire or overloading of the tire, both of which cause the tire to bear too much weight, which in turn causes a chemical breakdown in the tire. *See id.* at n.5.

[100] *Id.*

[101] *Id.*

[102] As Carlson testified, "when we look for the indicators of . . . over deflection . . . and eliminate those as a possible cause, then there is nothing else but a manufacturing defect." *Id.* at 1519. The district court noted that there was nothing inherently wrong with a process-of-elimination form of proof per se, as long as the underlying methods used were

opinion as inadmissible because it did not meet the reliability requirement established by *Daubert.*[103] The district court agreed, finding that Carlson's opinion satisfied none of the four admissibility criterion listed in *Daubert.*[104]

On appeal, the Eleventh Circuit reversed the district court and held that *Daubert* applied only to scientific expert testimony and not to expert testimony based on personal observations or experience.[105] Writing for the Eleventh Circuit, Judge Birch stated that "*Daubert* does not create a special analysis for answering questions about the admissibility of all expert testimony" but rather "provides a method for evaluating the reliability of witnesses who claim scientific expertise."[106] Judge Birch found that Carlson's testimony was nonscientific because Carlson based his opinions on personal experience and observations rather than scientific principles and methodology.[107] Accordingly, the Eleventh Circuit held that the district court erred in applying *Daubert* to Carlson's testimony.[108]

The Supreme Court reversed the Eleventh Circuit, holding that the reliability requirement set forth in *Daubert* applied to all expert opinion testimony whether "skill- or experience-based."[109] Following this preliminary decision

scientifically valid. *Id.* at 1520 n. 7.

[103] *Id.* at 1519-20 (stating that the defendant's rooted their collective motion for summary judgment partly on the ground that Carlson's testimony was inadmissible).

[104] *Id.* at 1521.

[105] *See Carmichael*, 131 F.3d at 1436 (holding that *Daubert* applies only to "scientific" testimony and not to "technical" or "specialized" testimony, thereby drawing a distinction within Federal Rule of Evidence 702).

[106] *Id.* at 1434 (quoting *U.S. v. Sinclair*, 74 F.3d 753, 757 (7th Cir. 1996)). In *Sinclair*, the Court explicitly limited the application of *Daubert* to "scientific" testimony. *Sinclair*, 74 F.3d at 757.

[107] *Carmichael*, 131 F.3d at 1436 (finding that Carlson's expertise resulted from years of looking at mangled tires, not from any specific theory of physics or chemistry).

[108] *Id.*

[109] *Id.* at 151. In fact, the Court specifically acknowledges that when an expert witness's expertise is based solely on experience, some of the *Daubert* rule's questions can help evaluate the reliability of the testimony. *Id.* Thus, one of the critical questions that *Kumho* resolved was the applicability of the *Daubert* admissibility test to nonscientific expert testimony. The *Kumho* Court noted that Rule 702 of the Federal Rules of Evidence makes no "relevant distinction" between scientific knowledge and nonscientific knowledge. *Id.* According to the *Kumho* Court, trial courts should apply the *Daubert* factors "where they are reasonable measures of the reliability of expert testimony," regardless of whether the expert is a scientist. *Id.* at 152. The difficulties that courts may face in applying the *Daubert* test to nonscientific expert testimony is beyond the scope of this Article and has been addressed by others. *See e.g.* K. Isaac deVyver, *Opening the Door but Keeping the Lights Off: Kumho Tire Co. v. Carmichael and the Applicability of the Daubert Test to Nonscientific Evidence*, 50 Case W. Res. L. Rev. 177 (1999); Kimberly M. Hrabosky, *Kumho Tire v. Carmichael: Stretching Daubert Beyond Recognition*, 8 Geo. Mason L. Rev. 203 (1999); *see also* J. Brook Lathram, *The "Same Intellectual Rigor" Test Provides an Effective Method for Determining the Reliability of All Expert Testimony, Without Regard to*

requiring judges to "gatekeep" for all proffered expert testimony envisioned by Federal Rule of Evidence 702,[110] the *Kumho* Court clarified that the four reliability factors described in *Daubert* are not applicable in all cases.[111] Justice Breyer then proceeded to do what Justice Blackmun had failed to do in *Daubert*: develop a new scientific admissibility standard and apply it to the specific facts of the case at hand.[112]

In *Kumho,* Justice Breyer engaged in a thorough and detailed assessment of the precise scientific tests, methodologies, and conclusions that the plaintiffs presented to the district court.[113] This reanalysis required the Supreme Court to unearth and evaluate numerous case-specific facts that supported the district court's determination that plaintiffs' expert evidence was inadmissible.[114] For example, according to Justice Breyer, plaintiffs (1) failed to provide the district court with any evidence that other experts in this field would have used the same two factor analysis employed by Carlson, (2) did not establish that tire experts generally made the types of distinctions upon which Carlson based his opinion, and (3) failed to provide the district court with any reference to, or support for, Carlson's methodology in any relevant publications.[115] Justice Breyer's detailed reevaluation of the underlying facts is an effort to model the admissibility inquiry that trial judges must undertake when they perform their gatekeeping roles.

On its face, *Kumho* appears to do nothing more than restate the test developed in *Daubert* to govern the admissibility of scientific evidence. Accordingly, *Kumho* has been widely cited in judicial and scholarly discussions as affirming *Daubert,* with the caveat that it expanded the *Daubert* gatekeeping role to include testimony by all experts with scientific, technical, or other specialized non-empirical knowledge,[116] and added the requirement

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Whether the Testimony Comprises "Scientific Knowledge" or "Technical or Other Specialized Knowledge," 28 U. Mem. L. Rev. 1053 (1998).

[110] The Court noted that Rule 702 "makes no relevant distinction between scientific knowledge and technical or other specialized knowledge" and "applies its reliability standard to all . . . matters within its scope." *Kumho Tire Co. v. Carmichael*, 526 U.S. 137, 147 (1999).

[111] *See id.* at 150.

> The conclusion, in our view, is that we can neither rule out, nor rule in, for all cases and for all time the applicability of the factors mentioned in *Daubert,* nor can we do so for subsets of cases categorized by category of expert or by kind of evidence. Too much depends on the particular circumstances of the particular case at issue.

Id.

[112] *Id.* at 153.

[113] *See id.* at 153-58 (reanalyzing in detail Carlson's specific methodology in light of the court's opinion).

[114] *See id.*

[115] *See id.* at 157 (examining the record and finding no indication that other experts in the industry use Carlson's test or methodology).

[116] *See* Edward J. Imwinkelried, *The Taxonomy of Testimony Post-Kumho: Refocusing*

that an expert employ "the same level of intellectual rigor" in the courtroom as in her field of research.[117] Close examination, however, reveals that Justice Breyer's majority opinion in *Kumho* is a significant clarification of *Daubert* that shifts the focus of the judicial admissibility inquiry. In fact, *Kumho* is intended to transform and improve judicial decision-making in cases that involve science, technology, or other areas of specialized knowledge.

As discussed above, *Daubert* created a two-step test to govern the admissibility inquiry for scientific evidence.[118] The first step requires judges to determine whether the expert testimony is "scientific knowledge."[119] This step appears to demand that judges first assess the general theoretical and methodological reliability/validity of proffered scientific evidence. The second step, which must follow a finding that the evidence is "scientific knowledge," requires judges to decide whether the evidence "fits," or is relevant to, the facts at issue.[120]

There are two inherent structural problems with the placement and apparent requirements of the first step of *Daubert* that have been unrecognized by courts or commentators despite the flurry of critique that followed this decision.[121] The first is a problem of interpretation. Requiring non-scientist judges first to determine whether proposed expert testimony is "scientific knowledge," *before* exploring the relevance of the testimony to the facts at hand, seems to distort the admissibility decision by forcing the judge to focus on a potentially infinite amount of evidence that is probably irrelevant to the dispute at hand. The second problem is one of application. Judges attempting to implement *Daubert* may mistakenly assume that because they have little experience or expertise interpreting and evaluating competing scientific theories or methodologies, they should admit all but the most patently bogus, scientific evidence and allow the jurors to resolve discrepancies as questions of weight.[122]

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on the Bottomlines of Reliability and Necessity, 30 Cumb. L. Rev. 185, 209 (2000) (noting that prior to *Kumho,* "the objective validity of a non-scientific expert's premises was essentially exempt from any scrutiny"). According to Imwinkelried, "*Kumho* not only establishes that *Daubert* is still good law; it also expands the scope of the *Daubert* doctrine. In particular, *Kumho* announces that *Daubert's* reliability/validation standard applies to all types of expert testimony, non-scientific as well as scientific." *Id.* at 211.

[117] *Kumho*, 526 U.S. at 152.

[118] *See supra* Part I(A) (discussing the two-step test created in *Daubert*).

[119] According to Justice Blackmun, "[f]aced with a proffer of expert scientific testimony, then, the trial judge must determine at the outset... whether the expert is proposing to testify to (1) scientific knowledge...." *Daubert*, 509 U.S. 592 (describing the first step of the *Daubert* test).

[120] The *Daubert* Court identified the second step of the inquiry as determining whether the "scientific knowledge... will assist the trier of fact to understand or determine a fact in issue." *Id.* at 592.

[121] *See supra* n. 9 (discussing the scholarly criticism of *Daubert*).

[122] The Advisory Committee Notes to the May 2000 amendments to Federal Rule of

A careful reading of *Kumho* indicates that Justice Breyer was likely motivated by judges' problems understanding and applying *Daubert.* More specifically, Justice Breyer implicitly acknowledged in the majority opinion that the first (general reliability/validity) step of *Daubert* may have imposed an insurmountable hurdle for the federal courts. This reading of *Kumho* is supported by Justice Breyer's almost exclusive focus on the second step of the *Daubert* test, the fit/relevance prong.

> [T]he specific issue before the [district] court was not the reasonableness in general of a tire expert's use of a visual and tactile inspection, [but was instead] the reasonableness of using such an approach . . . to draw a conclusion regarding the particular matter to which the expert testimony was directly relevant.[123]

Thus, according to the *Kumho* majority, a properly conducted admissibility inquiry should focus on the fit/relevance of the proffered evidence.[124]

This restructuring of the admissibility standard places the assessment of scientific validity squarely within the context of a relevance inquiry, thereby providing future courts with a more familiar and readily implemented standard. Using this newly reformulated test, the *Kumho* Court concludes that "the question before the trial court was specific, not general[:]. . . the trial court had to decide whether *this particular expert* had sufficient specialized knowledge to assist the jurors 'in deciding *the particular issues* in the case.'"[125]

This Article's interpretation of *Kumho,* as a significant reformulation of *Daubert,* is further supported by the concurring opinion by Justices Scalia, Thomas, and O'Connor. It is particularly notable that these justices appear to disagree with the majority's refocusing of the admissibility inquiry to emphasize relevance and eliminate or diminish the Court's inquiry into more general questions of scientific reliability/validity.[126] Justices Scalia, Thomas, and O'Connor concluded that the district court properly excluded testimony

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Evidence 702 addressed this concern by noting that "[a] review of the case law after *Daubert* shows that the rejection of expert testimony is the exception rather than the rule." *See* David L. Faigman, *et al., "How Good is Good Enough?: Expert Evidence Under Daubert and Kumho,"* 50 Case W. Res. L. Rev. 645, 665 (2000) (finding that "in the forensic context, courts have long admitted a surfeit of expertise with little or no evaluation of the foundation upon which the opinion rests."); Jay P. Kesan, *Symposium Drug Development: Who Knows Where the Time Goes?: A Critical Examination of the Post-Daubert Scientific Evidence Landscape,* 52 Food Drug L.J. 225, 239-40 (1997) (reviewing numerous post-*Daubert* cases and concluding that "the quantum of scientific information that must undergird an expert's methodology to render it scientifically valid and admissible under *Daubert* is quite minimal").

[123] *Kumho,* 526 U.S. at 153.

[124] *Id.*

[125] *Id.* at 156 (emphasis added) (citations omitted) (articulating that whether Carlson's method's were *ever* appropriate was not at issue).

[126] *Id.* at 158.

from plaintiff's expert.[127] In their view, however, the *Kumho* decision simply upheld the lower court's broad and general "discretion to choose among reasonable means of excluding expertise that is false and science that is junky."[128]

Thus, the concurring opinion in *Kumho* demonstrates that at least three members of the Court did not share Justice Breyer's conclusion that the lower court decision did reject, or should have rejected, a bad fit between potentially valid scientific theory and methodology and the specific facts before that court. Instead, Justices Scalia, O'Connor, and Thomas understood *Kumho* as the Court's imprimatur on the district court's conclusion that, in a general sense and under the first step of *Daubert,* plaintiff's expert's testimony was junk science.

2. Subsequent Decisions from the Federal Courts Support a New Kumho Admissibility Test

The significance of Justice Breyer's reformulation of the *Daubert* inquiry is just beginning to manifest itself in decisions of the federal courts. In January 2000, the Seventh Circuit in *United States v. Brumley*[129] became the first of the circuit courts to explicitly acknowledge that *Kumho* had refocused the *Daubert* admissibility inquiry on the second fit/relevance step of the *Daubert* test.[130] According to the Seventh Circuit, "[t]he Supreme Court in *Kumho Tire* explained that the *Daubert* 'gatekeeper' factors had to be *adjusted to fit the facts of the particular case at issue*, with the goal of testing the reliability of the expert opinion."[131] In September 2000, the Seventh Circuit once again concluded that *Kumho* had transformed the *Daubert* test.[132] In doing so, however, the court added the bizarre limitation that the new *Kumho* test applied only to technical testimony, and not to expert testimony based on scientific or other specialized knowledge.[133] *Kumho* specifically belies this distinction.[134] Hopefully the Seventh Circuit will excise this feature from its

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[127] *Id.*

[128] *Id.*

[129] 217 F.3d 905 (7th Cir. 2000).

[130] *Id.* at 911.

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

[132] "[W]ith respect to technical testimony, the 'Supreme Court in *Kumho* explained that the *Daubert* 'gatekeeping' factors had to be *adjusted to fit the facts of the particular case at issue*, with the goal of testing the reliability of the expert opinion.'" *NutraSweet Co. v. X-L Engineering*, 227 F.3d 776 (7th Cir. 2000) (*quoting Brumley*, 217 F.3d at 911(emphasis added).

[133] *See id* at 788 (alleging that *Kumho* explained only how the *Daubert* test should apply with respect to technical testimony).

[134] "[I]t would prove difficult, if not impossible, for judges to administer evidentiary rules under which a gate-keeping obligation depended upon a distinction between 'scientific' knowledge and 'technical' or 'other 'specialized' knowledge." *Kumho*, 526 U.S.

otherwise accurate reading of *Kumho* as it develops its doctrine.

In addition to these Seventh Circuit decisions, the Sixth Circuit, in May 2000, specifically noted that "[t]he Supreme Court in Kumho indicated that the standards set forth in Daubert, depend[] on the particular circumstances of the particular case . . . ."[135] More recently, the Southern District of New York embraced a similar reading of *Kumho* when it noted, in February 2001, that the *Kumho* Court was "less absorbed . . . in formulating general rules for assessing reliability . . . and more concerned about directing judges to concentrate on the particular circumstances of the particular case at issue."[136] In fact, Judge Sweet, writing for the district court, supported his decision by citing the Federal Judicial Center's conclusion that *Kumho* demonstrated that the Court is concerned more with focusing judges on the particular facts at issue in each case than on taxonomy of expertise.[137]

Recent decisions from other federal circuit and district courts also support this reading of *Kumho*. In *Wheeling Pittsburgh Steel Corp. v. Beelman River Terminals, Inc.*,[138] the Eighth Circuit emphasized the *Kumho* requirement of fit/relevance, finding that "it is the responsibility of the trial judge to determine whether a particular expert has sufficient specialized knowledge to assist jurors in deciding the specific issues in the case."[139] In *Berry v. Crown Equipment Corp.*, [140] a Michigan federal district court defined the post-*Kumho* role of the district judge as follows:

> The court is to examine not the qualifications of a witness in the abstract, but whether those qualifications provide a foundation for a witness to answer a specific question. Thus, the trial court must determine whether the expert's training and qualifications relate to the subject matter of his proposed testimony. The trial court has to decide whether this particular expert has sufficient specialized knowledge to assist the jurors in deciding the particular issues in the case.[141]

In 1999, a Wisconsin federal district court articulated a similar emphasis on the fit/relevance component of the *Kumho* test in *National Football League*

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at 148. While *Kumho* dealt with technical testimony, the Court made clear that its thinking should apply equally to scientific testimony.

[135] *U.S. v. Smithers*, 212 F.3d 306, 314 (6th Cir. 2000) (quoting *Kumho Tire Co.*, 526 U.S. 150, to note that while the *Daubert* test has not been abandoned, it must be flexibly applied).

[136] *Primavera Familienstifung v. Askin*, 130 F.Supp.2d 450, 522 (S.D.N.Y. 2001) (quoting *Reference Manual on Scientific Evidence*, *supra* n. 3, at 21 (internal quotation marks omitted)).

[137] *See id.*

[138] 254 F.3d 706 (8th Cir. 2001).

[139] *Id.* at 715 (citing *Kumho*, 526 U.S. at 156, and examining whether the expert at issue qualified as an admissible expert with respect to the particular issues at hand).

[140] 108 F. Supp. 2d 743 (E.D. Mich. 2000).

[141] 108 F. Supp. 2d 743, 749 (quotations and citations omitted).

Properties, Inc. v. Prostyle, Inc.[142] In that case, the court noted that after the *Kumho* and *Daubert* decisions, non-case-specific information standing alone does not sufficiently assist the jury to warrant admittance at trial.[143] At least four additional federal district courts have relied upon similar relevance/fit based analyses to decide questions of scientific admissibility.[144] Together, these cases confirm a shift in the federal courts' reading of *Kumho*. This new reading reflects the primacy of a fact-specific emphasis and a movement away from the general validity step of the *Daubert* test.

C. *The Influence of Justice Breyer's Personal Jurisprudence*

> *[N]either the difficulty of the task nor any comparative lack of expertise can excuse the judge from exercising the "gatekeeper" duties . . . .*[145]

The *Kumho* Court's restructuring of *Daubert* is not accidental, nor is it a coincidence that Justice Breyer authored this influential decision. It may be impossible to ever discern the exact scope of Justice Breyer's influence on the *Kumho* decision. It seems safe to assume, however, that Justice Breyer used his influence as author of the majority opinion to guide the Court's analysis. Justice Breyer is the only member of the Court repeatedly to express his belief that the legitimacy and accuracy of legal decision-making is threatened when courts misunderstand or misuse science.[146] Thus, any interpretation of

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[142] 57 F. Supp. 2d 665 (E.D. Wis. 1999).

[143] 57 F. Supp. 2d 665 at 672 (quoting the U.S. Supreme Court in *Kumho*) ("The question before the trial court was specific, not general. The trial court had to decide whether this particular expert had sufficient specialized knowledge to assist the jurors in deciding the particular issues in the case.").

[144] *See Meineker. v. Hoyts Cinema Corp.*, 2001 U.S. Dist. LEXIS 8846 (N.D. N.Y. June 25, 2001) ("Ultimately, the court must determine whether the expert has sufficient specialized knowledge to assist the trier of fact in deciding the particular issues in the case."); *Sittig v. Louisville Ladder Group LLC*, 136 F. Supp. 2d 610 (W.D. La. 2001) (stating that experts must have a "degree of knowledge, skill, experience, or training to testify about [the case specific issues]"); *Rothfos Corp. v. M/V Nuevo Leon*, 123 F. Supp. 2d 362 (S.D. Tx. 2000) (concluding that *Kumho* recognized the *Daubert* test must always be fact specific); *Grdinich v. Bradlees*, 187 F. Supp. 2d 77 (S.D.N.Y. 1999) (noting that the expert must have "specialized knowledge to assist the jurors in deciding the particular issues in the case"); *Gray et al v. Briggs*, 45 F. Supp. 2d 316 (S.D.N.Y. 1999) (arguing that expert testimony must help determine "particular issues in the case").

[145] *Joiner*, 522 U.S. at 148 (Breyer, J., concurring) (providing a preview of his strong interest in questions of science and law).

[146] Breyer stated:

> This [*Daubert*] requirement will sometimes ask judges to make subtle and sophisticated determinations about scientific methodology and its relation to the conclusions an expert witness seeks to offer—particularly when a case arises in an arena where the science itself is tentative or uncertain, or where testimony about general risk levels in human beings or animals is offered to prove causation.

Supreme Court doctrine on questions involving science and law must consider the powerful influence of Justice Breyer's personal jurisprudence in light of his oft-repeated goal of achieving more effective interdisciplinary integration.[147]

The *Kumho* opinion is replete with evidence that Justice Breyer's personal jurisprudence heavily influenced the Court's analysis. It also appears that Justice Breyer may have used an instrumentalist approach to achieve what he thought best for the federal courts. For example, Justice Breyer has characterized the *Kumho* district court opinion as focused "not [on] the reasonableness in general of the [scientific evidence],"[148] but instead on the "reasonableness of using such an approach . . . to draw a conclusion regarding the particular matter to which the expert testimony was directly relevant."[149] This description of the trial court's conclusions, which provides the foundation for his opinion, is simply not accurate. In addition, Justice Breyer's assumption that the district court limited its analysis to the narrow issue of "whether [the] particular expert had sufficiently specialized knowledge to assist jurors in deciding the particular issues in the case,"[150] is similarly unsupported. In contrast to the Supreme Court's assertions, the trial court in *Kumho* actually had engaged in a fairly routine and formulaic application of *Daubert*, focusing primarily on the first (general validity) step of the *Daubert* test.[151] According to the district court,

> [t]his Court's *Daubert* analysis illustrates that none of the criteria set forth by the Supreme Court for admissibility of scientific evidence under Rule 702 have [sic] been satisfied in this case. The *Daubert* Court assigned to trial courts "the task of ensuring that an expert's testimony both rests on a reliable foundation and is relevant to the task at hand." The Court has a responsibility to serve as a gatekeeper, ensuring that purportedly expert testimony does not reach a jury unless that testimony is reliable and reasonable.[152]

Thus, the *Kumho* district court's ultimate conclusion emphasized the more general concerns of the first prong of the *Daubert* test, scientific reliability/validity, and gave short shrift to the second prong of the *Daubert* test, evidence of relevance or fit.

Id. at 147-48 (concluding that judges must adeptly handle science related areas to ensure that the truth will be ascertained).

[147] See examples *supra* nn. 3, 11.

[148] *Kumho*, 526 U.S. at 153 (stating that the issue facing the court was not, as the respondents alleged, whether the tire expert's methods were generally acceptable).

[149] *Id.* (emphasizing the importance of a fact-specific analysis of testimony).

[150] *Id.* at 156 (characterizing the question faced by the trial court as specific, not general).

[151] *See Carmichael v. Samyang Tires, Inc.*, 923 F. Supp. 1514, 1520-21 (S.D. Ala. 1996) (outlining and subsequently applying the four reliability factors suggested in *Daubert* as helpful to determining general scientific validity).

[152] *Id.* at 1522 (citations omitted) (finding testimony too unreliable, speculative, and attenuated to be admissible).

Another indication that the *Kumho* majority's conclusion may reflect the influence of Justice Breyer's personal jurisprudence is the fact that most of the discussion in the majority opinion is wholly unnecessary to the resolution of the question raised by the Eleventh Circuit. The fact that the majority addressed issues beyond the narrow question of whether *Daubert* applied to technical expert testimony did not escape Justice Stevens, who dissented from much of the majority opinion. According to Justice Stevens, the Court should have simply held that "the District Court's decision in this case—not to admit certain expert testimony—was within its discretion and therefore lawful."[153] Justice Stevens also criticized the Court's decision to reach out to decide questions not raised by the certiorari petition as unfair to litigants.[154] In light of this criticism, it is reasonable to interpret Justice Breyer's application of his reformulated test to the facts before the district court as an attempt to provide a model of judicial inquiry for lower courts to follow.[155]

To the extent that problems understanding and implementing *Daubert* have been caused or exacerbated by the admissibility test created in that case, Justice Breyer has offered future judges a possible solution through the new test created in *Kumho.* It is also clear, from Justice Breyer's writings and comments, that *Kumho* reflects his personal jurisprudence. Moreover, this decision appears to symbolize a specific pragmatic solution to a cumbersome and divisive problem.[156] At the same time, the creation of a new *Kumho* test reveals the following irony: although Justice Breyer himself clearly respects the scientific process, he recognizes that the law does not proceed on the scientific model, any more than science proceeds on the legal model. In fact, law is sometimes best advanced by the most unscientific method of all, the deliberate realignment of basic principles and mechanisms to reflect the priorities and jurisprudence of a single powerful percipient individual.

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[153] *Kumho*, 526 U.S. at 142 (1999) (granting district courts broad latitude in deciding how to determine reliability).

[154] *Id.* at 159 (Stevens, J., dissenting) (contending that the court should not indulge in excessive dicta in cases such as *Kumho*).

[155] A recent case from the Sixth Circuit appeared to recognize that Justice Breyer has set the standard for assessing the judicial inquiry when, citing *Kumho,* the court engages in a thorough assessment of plaintiff's expert's science and methodology. *See United States v. Smithers*, 212 F.3d 306, 315 (6th Cir. 2000) (noting that the Supreme Court's *Kumho* decision considered the district court's possible examination of the *Daubert* factors).

[156] Professor Richard J. Pierce, Jr., has examined Justice Breyer's extensive writings in an effort to characterize his judicial philosophy. *See* Richard J. Pierce, Jr., *Justice Breyer: Intentionalist, Pragmatist, and Empiricist*, 8 Admin. L. J. Am. U. 747 (1995). According to Professor Pierce, Justice Breyer is a "dedicated pragmatist" who, during his confirmation hearings, described his goal as making law work for people. *Id.* at 748. Professor Pierce also concludes that Justice Breyer has a "deep respect for contextual facts" and that "[h]is normative prescriptions are invariably contingent on contextual facts." *Id.* at 750. This view of Justice Breyer, as a jurist focused on the practical implementation of law to specific facts is wholly consistent with the Court's approach in *Kumho.*

On its own, a new admissibility standard takes us only part of the way towards more effective integration of science into law. Justice Breyer recently wrote that the most "obvious" impediment to the developing interdependence of science and law is the fact that "judges lack the scientific training that might facilitate the evaluation of scientific claims or the evaluation of expert witnesses who might make such claims."[157] To alleviate this problem, legal scholars and practitioners who must use science to understand or adjudicate legal questions will need to develop an understanding of basic scientific terminology, methodology, and statistical analysis.

II. HONING OUR SCIENTIFIC TOOLS

A. *Developing Our Scientific Sophistication*

> *In spite of centuries of attention by scientists and philosophers of science, no concise definition of science has ever been accepted by the community of scientists and scholars.*[158]

In 1999, Justice Breyer, with the backing of a majority of the Supreme Court, provided the federal judiciary with a new test intended to guide the courts on questions involving the admissibility of scientific, technical, and other specialized evidence. This test, while certainly an improvement over *Daubert*, is not enough.

Basic scientific language,[159] theory, and methodology are not only foreign, but may be an anathema to lawyers familiar with legal rhetoric, jurisprudential theory, and the process of adjudication. It should be obvious that legal scholars and practitioners must enhance their scientific sophistication to understand and resolve cases that involve scientific evidence. In fact, *Daubert* and its progeny require that judges assess scientific reliability and direct the judicial inquiry to factors such as scientific testability, peer review and publication, and error rates.[160] As one commentator has observed:

> Many people have become alienated from science and the scientific habits of thought—at a time when we need science more than ever to help us find our way though an increasing number of serious and complicated

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[157] *Reference Manual on Scientific Evidence*, *supra* n. 3, at 4.

[158] Shermer, *supra* n. 18, at 164.

[159] Many of the problems that lawyers have with science may be attributed poor interdisciplinary communication. *See e.g.* Gina Kolata, *Health Care Advice: A Matter of Cause, Effect and Confusion*, N. Y. Times at D1, D6 (April 25, 2000) (describing the difficulties in communication and comprehension between scientists and nonscientists). "Scientists and the public alike use words like 'prevents' and 'protects against' and 'lowers the risk of' when they are discussing evidence that is suggestive, and hypothesis-generating, as well as when they are discussing evidence that is as firm as science can make it." *Id.*

[160] *Daubert*, 509 U.S. at 594 (discussing the factors relevant to the determination of whether a particular method or technique is admissible).

> questions involving risks to health and safety. To reverse the alienation we need a better public understanding of science . . . including an understanding of the nature of evidence, the concepts of chance and error, and the value of skepticism.[161]

Judges should not use their scientific naivete to excuse a reluctance to engage in a thorough analysis of the quality of proffered scientific evidence.

> Circumventing the Daubert mandate to examine the underlying validity of proposed expert testimony is all the more shocking because performing the Daubert analysis is not difficult. There are judges who apply Daubert routinely and well and whose rigorous standards should serve as a model to those overwhelmed by their gatekeeping responsibilities.[162]

As Justice Breyer explained in his concurrence in *Joiner*:[163]

> Of course, neither the difficulty of the task nor any comparative lack of expertise can excuse the judge from exercising the 'gatekeeper' duties that the Federal Rules of Evidence impose . . . . To the contrary, when law and science intersect, those duties often must be exercised with special care.[164]

To understand fundamental scientific concepts, we do not need to become amateur scientists.[165] This misconception, combined with a general fear of things scientific, may be partially responsible for basic misunderstandings on the part of many judges and lawyers involved in determining the admissibility of scientific evidence.[166]

The first set of problems encountered in any attempt to better integrate science into legal practice or legal analysis involves misunderstandings between scientific and legal language. For example, problems frequently

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[161] Marcia Angell, *Evaluating the Health Risks of Breast Implants: The Interplay of Medical Science, the Law, and Public Opinion,* 334 New Eng. J. Med. 1513, 1517 (1996) (describing the frustration some feel when confronted with the inconsistent decisions in cases relying on scientific evidence).

[162] Beecher-Monas, *supra* n. 48, at 85 (providing examples of judges who have effectively applied the *Daubert* test).

[163] *General Electric Co. v. Joiner,* 522 U.S. 136, 147-50 (1997).

[164] *Id.* at 148 (Breyer, J., concurring).

[165] *See id.* at 148 (Breyer, J., concurring) ("[J]udges are not scientists and do not have the scientific training that can facilitate the making of such [scientific] decisions."). Justice Breyer believed that a lack of specialized scientific training should not keep judges from fulfilling their gatekeeping duties. *Id.*

[166] *See* Fed. R. Evid. 702 (advisory committee's note) ("A review of the caselaw after *Daubert* shows that the rejection of expert testimony is the exception rather than the rule."); Beecher-Monas, *supra* n. 48, at 58 (describing how judges try to avoid dealing with the science that supports proffered scientific evidence). *See also* Kesan, *supra* n. 119, at 239-40 (reviewing numerous post–Daubert cases and concluding that a only minimal amount scientific information must undergird an expert's methodology to render it scientifically valid and admissible under the *Daubert* test).

occur when non-scientists believe that something either causes—or does not cause—a disease in a particular person. Accordingly, it should not surprise anyone that three of the critical cases decided by the Supreme Court involving questions of science and law turned on the plaintiffs' ability to demonstrate causation.[167] The nonscientist's understanding of causation may be reinforced by the legal questions that we seek to resolve and by our processes of adjudication. Certain tort actions, for example, require the factfinder to determine, by a preponderance of the evidence, whether exposure to defendant's product caused plaintiff's injuries.[168] Thus, lawyers and judges appear to learn from experience that questions involving specific medical causation, such as whether defendant's product caused plaintiff's injuries, are proper and necessary to litigation.

To a medical scientist, the question of specific causation is not only unanswerable; it is absurd.[169] Scientists never treat causation as a yes/no question, nor do responsible ones believe that it is possible to use scientific methods to determine individual causation. In fact,

> good scientists rarely reach absolute conclusions. Particularly in medical research, certainty is extremely hard to come by. Instead, medical researchers almost always speak in terms of probabilities. . . . Very few studies are by themselves definitive . . . [and] [e]ven then, the studies taken together merely add to the probability that the conclusion is correct, without proving it absolutely.[170]

Instead, scientists view questions of causation as measurements of risk. A responsible scientist can never say with certainty that a defendant's product caused a particular plaintiff's disease. As a result, misunderstandings and miscommunications abound when the law asks for a finding of specific legal

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[167] *See Kumho*, 526 U.S. at 137; *Joiner*, 522 U.S. at 136; *Daubert*, 509 U.S. at 579. Each case involves the attempted use of expert testimony to prove causation as well as the subsequent legal arguments concerning the admissibility of such testimony).

[168] *Reference Manual on Scientific Evidence*, *supra* n. 3, at 32 (explaining that in toxic tort cases, the causal mechanism is often unknown, so establishing causation involves using scientific evidence to infer cause and effect). *Id.*

[169] *See* Beecher-Monas, *supra* n. 45, at 1098-99 (describing the attempt to achieve scientific certainty as "an unnecessary exercise in existential angst").

> [N]o matter how persuasive epidemiological or toxicological studies may be, they do not show individual, specific causation although they might enable a probabilistic judgment about the association between a particular chemical exposure and human disease on a population level. . . . Even if epidemiologists and toxicologists are able to identify correlations between exposure to a given chemical and a disease, their summary statistical statements apply only to the group studied, not to the individual members of the group.

Id.

[170] Angell, *supra* n. 18, at 96-97 (comparing seemingly contradictory elements of science such as the presentation of objective evidence against the reluctance to use such evidence to make absolute statements in individual cases).

causation, while scientific causation can be expressed only as a mathematical quantification of increased but generalized risk.

When Justice Breyer redefined "the relevant issue" of the *Kumho* inquiry to be "whether the expert could reliably determine the cause of *this* tire's separation," he may have inadvertently increased the gap between scientific and legal definitions of causation.[171] Scientific notions of causation encompass the concept of uncertainty and are necessarily generalized predictions of increased risk. Thus, by focusing on an expert's ability to determine the cause of a particular event, the *Kumho* Court could theoretically widen the interdisciplinary gap by creating a false expectation that experts can testify to specific causation based on inferences derived from scientific studies.[172]

The second problem that we encounter when we attempt to use science to resolve legal disputes arises from disparities between legal and scientific processes. As one commentator observed:

> [L]aw and science represent two strikingly different ways of thinking, which reflect their different methods. The law frames questions in adversarial terms, and lawyers see problems as best resolved by controlled argument. In contrast, the scientific method is (ideally) not adversarial, but cooperative, and scientists usually find answers in the slow accumulation of evidence from many sources. The different ways of thinking are so ingrained that they may be virtually unconscious.[173]

Lawyers and judges are generally comfortable asking and answering questions in a legal environment governed by the requirements of representation, evidentiary and procedural rules, and stringent time limits. This may seem odd to scientists, some of whom view the litigation process as uncomfortable, unfamiliar, and unlikely to generate valid results. Scientists' problems with the legal process arise, in part, because science is less constrained by the requirement of immediate and final decision-making.[174] Most scientists, in

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[171] *Kumho*, 526 U.S. at 154.

[172] This raises the question of whether those attempting to narrow the gap between science and law might argue for a different approach to civil liability focused on the question of whether, as a society, we should continue to punish toxic tort defendants for causing discrete injury to individual plaintiffs (which can never be determined with scientific certainty). Perhaps the punishable act at issue should be the act that can be established with some degree of scientific certainty—defendant's willingness to increase the generalized risk of a particular harm an a broader level. This approach may be explored, for example, in large class action lawsuits where the factfinder's focus is more diffuse. Although cleaving or distancing legal responsibility from causation may raise other problems, our current practice, to the extent that it attempts to establish individualized harm, may sometimes rest on nothing more than a convenient legal fiction.

[173] Angell, *supra* n. 18, at 28-29 (explaining what happens when the scientific mind encounters the courtroom).

[174] Scientists, unlike judges and lawyers, generally have the luxury of time, which likely improves the quality of their conclusions. *See* Foster & Huber, *supra* n. 19, at 83 (noting that the scientific process sets forth numerous "erroneous" discoveries in the process of

their own fields, are permitted to pursue knowledge in the relative anarchy of collaborative discussion, with time for debate and an expectation of peer-review of new theories and developments.[175]

A third problem arises when nonscientists are uncomfortable or unfamiliar with the core statistical concepts that underlie all empirical data. Judges are routinely asked to understand statistics, and while they do not have to become expert statisticians, they are expected to familiarize themselves with statistical analysis.[176] Failure to do so has a negative impact on the legal decision-making process. This problem can be alleviated if we recognize that many legal decisions actually involve probabilistic reasoning and, at the same time, we attempt to improve our understanding of basic statistical concepts.[177]

As Justice Breyer recently explained, "[t]he search is not a search for perfection, nor is it even a search for scientific precision. A judge is not a scientist and a courtroom is not a scientific laboratory."[178] It is overly simplistic, however, to assume that acquiring a basic understanding of scientific jargon, methods, or statistics will enable us to assess the scientific validity of all proposed expert testimony. Not only will some cases be too technical or complex for judges and lawyers to comprehend, but science is so

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reaching a plausible one). In the opinion of one commentator, "[t]he much-praised reliability of science occurs only in the long term; in the short term, science is as flawed, as error-prone, and as subject to manipulations and intellectual passions as any other human activity." *Id.*

175 The *Daubert* decision itself acknowledges that

> there 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. . . . [The] Rules of Evidence [are] designed not for the exhaustive search for cosmic understanding but for the particularized resolution of legal disputes.

Daubert, 509 U.S. at 596-97.

176 Justice Breyer described the recent burden on the Supreme Court, with respect to statistics as follows:

> In each of these two cases [*Hunt v. Cromartie*, 199 S.Ct. 1545 (1999) and *Dept. of Com. v. U.S. H. of Reps.*, 119 S. Ct. 765 (1999)], we judges were not asked to become expert statisticians, but we were expected to understand how that statistical analyses worked. Trial judges today are asked routinely to understand statistics at least as well, and probably better.

Reference Manual on Scientific Evidence, *supra* n. 3, at 2. Legal scholars and practitioners attempting to acquire a basic understanding of statistics might look at Hans Zeisel & David Kaye, *Prove It with Figures: Empirical Methods in Law and Litigation* (1997).

177 For an example of an effort to assist judges manage cases involving scientific issues, see generally *Reference Manual on Scientific Evidence*, *supra* n. 3.

178 Associate Justice Stephen J. Breyer, Speech, "The Interdependence of Science and Law" (Association for the Advancement of Science Annual Meeting and Science Innovation Exposition, Feb 16, 1998) <http://aaas.org/meetings/1998/breyer98.htm> ("Courts must avoid that kind of serious scientific mistake (which once led one court, for example, to hold that dropping a can of orange juice caused breast cancer). They must aim for decisions that, roughly speaking, approximately reflect the scientific state of the art.").

broad that language and methodologies vary significantly across scientific disciplines.[179] A better understanding of the proper admissibility inquiry, combined with a basic understanding of scientific methodology, is merely a first step. These tools will enable us to recognize the complex scientific questions that require additional guidance to help us craft creative methods for enhancing our integration of science into law.

B. *Misunderstanding Critical Scientific Terminology*

1. Why We Need to Understand Critical Scientific Terminology

Judges and lawyers need a basic understanding of the language of science. This is of particular importance when a word has a vastly different meaning in science than it does in law. *Daubert* and its Supreme Court progeny reflect various attempts to import scientific terminology into the standards that govern the admissibility of scientific evidence. Thus, without an elementary understanding of critical scientific terms of art, we will be unable to comprehend the proper standard of admissibility or make sense of proposed testimony from scientific experts.

In *Daubert*, the Supreme Court instructed that, for scientific evidence to be admissible, "[t]he subject of an expert's testimony must be 'scientific . . . knowledge.'"[180] According to Justice Blackmun, "in order to qualify as 'scientific knowledge,' an inference or 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."[181] Based on this brief introduction to the concept of "scientific knowledge," the Court required that future judges focus their admissibility inquiry on "the scientific *validity*—and thus the evidentiary relevance and *reliability*—of the principles that underlie a proposed submission."[182]

Daubert introduced the concepts of scientific "validity" and "reliability" to a federal bench and bar that likely knew little of the precise scientific meanings of these terms. Although *Daubert* appeared to equate scientific validity with evidentiary relevance and also to demand an analysis based on reliable scientific principles, subsequent decisions from the Court narrowed the judicial focus to the requirement of scientific "reliability." In 1997, four years after *Daubert*, Justice Thomas stated in *United States v. Scheffer* that "the exclusion

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[179] *See* Capra, *supra* n. 47 at 703 (contending that scientists in the field at issue are better equipped to determine the reliability of complex scientific testimony than are most judges).

[180] *Daubert.*, 509 U.S. at 589-90 (quoting Fed. R. Evid. 702) (articulating the benchmark criterion of admissibility under *Daubert*).

[181] *Id.* at 590 (discussing the meaning of "scientific knowledge" and its relationship to results arrived at through the scientific method).

[182] *Id.* at 594-95 (emphasis added) (commenting on the compatibility between the *Daubert* test and the inherent flexibility of Federal Rule of Evidence 702).

of *unreliable* evidence is a principal objective of many evidentiary rules."[183] The *Scheffer* majority attained this objective, without *Daubert* analysis, when it relied upon "good faith disagreement among experts and courts on the subject of polygraph *reliability*" to uphold a per se exclusion of polygraph test results.[184] In 1999, the *Kumho* Court reiterated the significance of scientific "reliability" when Justice Breyer noted that, after *Daubert* and Rule 702, expert witnesses have "testimonial latitude unavailable to other witnesses on the 'assumption that the expert's opinion will have a reliable basis in the knowledge and experience of his discipline.'"[185]

For judges and lawyers unfamiliar with scientific terminology, it may seem reasonable for the Court to use the terms "reliability" and "validity" interchangeably and without specific definition or differentiation.[186] The most recent version of the American Heritage Dictionary defines "reliable" as "yielding the same or compatible results in different clinical experiments or statistical trials,"[187] while "valid" is defined as "producing the desired results."[188] Thus, in common parlance there is no clear or obvious distinction between these two terms. This cannot, however, end the inquiry for lawyers and judges charged with understanding scientific expert testimony. Attaining a thorough understanding of the current admissibility standard requires us to learn how scientists use these terms to convey quite different concepts.

2. How to Improve Our Understanding of Critical Scientific Terminology

To a scientist, "reliability" and "validity" are terms of art that have different and precise definitions. The difference between scientific reliability and validity is belied by the Supreme Court's assertion in *Daubert* that "the difference between . . . validity and reliability may be such that each is different from the other by no more than a hen's kick."[189] If the Supreme

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[183] *Scheffer*, 523 U.S. at 309 (emphasis added) (discussing the purposes behind many evidentiary rules).

[184] *Id.* at 318 (Kennedy, J., concurring) (emphasis added) (highlighting the general disagreement among experts concerning polygraph reliability).

[185] *Kumho* 526 U.S. at 148 (quoting *Daubert*, 509 U.S. at 592).

[186] In fact, the *Daubert* Court specifically noted that numerous sources focus on the "reliability of evidence as ensured by the scientific validity of its underlying principles." *Daubert* 509 U.S. at 595 n.12 (1993) (acknowledging that the term "reliability" has specialized meaning within science that differs from evidentiary reliability). After describing these different approaches within the literature, the Court refused to explain or express an opinion on the particular details of such approaches. *Id.*

[187] *The American Heritage Dictionary of the English Language* 1474 (4th ed., Houghton Mifflin 2000).

[188] *Id.* at 1899.

[189] The Court's only effort to distinguish scientific reliability from scientific validity, and explain the differences between the legal and common meanings of these terms, appears in a footnote which reads, in part:

We note that scientists typically distinguish between 'validity' (does the principle

Court's admissibility standard for scientific evidence ignores the profound difference between scientific reliability and scientific validity, judges who try to apply this standard to proffered scientific evidence will very likely be confused. This confusion is engendered or exacerbated when legal practitioners and scientists use the same words but have an inconsistent understanding of their meaning.[190]

We should begin by understanding that "reliability," the term used most frequently by the Court as a proposed guide for judicial inquiry,[191] refers specifically to the ability of a second scientist to reproduce the results of an earlier experiment.[192] The proper distinction between scientific reliability and the related concept of scientific validity has been described as follows:

> As a term of art in science and statistics, *reliability* refers to the reproducibility of data. A reliable test can be repeated under identical circumstances and yield the same results. The results may be consistently *wrong*, but that is an issue of validity, not reliability.[193]

Thus,

> [a] scale, for example, is reliable if it reports the same weight for the same object time and again. It may not be accurate—it may always report a weight that is too high or one that is too low—but the perfectly reliable scale always reports the same weight for the same object.[194]

> support what it purports to show?) and 'reliability' (does application of the principle produce consistent results?).... "[T]he difference between accuracy, validity, and reliability may be such that each is distinct from the other by no more than a hen's kick.... In a case involving scientific evidence, *evidentiary reliability* will be based upon *scientific validity*."

Daubert, 509 U.S. at 590 n.9 (citation omitted).

[190] *See* Foster & Huber, *supra* n. 19, at 111 (suggesting that the *Daubert* opinion used the lay meaning of reliability, i.e., the quality of being trustworthy, safe, or sure, without ever considering the more precise scientific meaning of the word).

[191] Justice Breyer recently described the post-*Daubert* role of the federal judiciary as "determin[ing] whether purported scientific evidence is 'reliable' ...." *Reference Manual on Scientific Evidence*, *supra* n. 3, at 5.

[192] *See* Foster & Huber, *supra* n. 19 at 111 (explaining the relationship between scientific reliability and its underlying basis in experimental testability). The scientific definition of "reliability" appears to be frequently confused with its legal definition. "Reliability" has a precise meaning in law that is different from its scientific definition. Evidence is reliable if it has sufficient indicia of trustworthiness to be presented to the jury for its consideration. Mistaking scientific reliability for evidentiary reliability can lead to general confusion about the quality of proposed scientific expert testimony and the proper standards of admissibility.

[193] Foster & Huber, *supra* n. 19, at 111 (stating that scientific reliability is not a surrogate for the validity of experimental results). This same distinction is true in the social sciences. *See e.g.* John Monahan & Laurens Walker, *Social Science in Law* 54-55 (4th ed. 1998) (noting that reliability refers only to the consistency of test results).

[194] *Reference Manual on Scientific Evidence*, *supra* n. 3, at 102-03 (explaining scientific reliability in terms of consistent measurements yielding reproducible results).

Reliability is generally quantified through examination of the "sensitivity" and "specificity" of a particular test.[195] Sensitivity represents the probability that a test actually will detect the particular condition it was designed to detect.[196] Thus, a sensitive test should yield very few false negative results (i.e., failed attempts to identify those who have the condition), but it may yield false positive results (i.e., identify the condition when it does not in fact exist). Specificity is the probability that a test will detect *only* the particular condition for which it was designed.[197] Thus, a test with a high specificity should yield very few false positive results, but it may yield false negative results. A reliable test will ideally yield low rates of both false positive and negative results. Unfortunately, the *Daubert* Court does little to explicate the proper meaning or usage of "reliability" in the scientific context or elucidate the underlying concepts of sensitivity or specificity. According to one commentator,

> [w]hat makes *Daubert* confusing is that it utilizes both meanings of "reliable." The thrust of the opinion, including the listing of factors to be considered, supports a conclusion that "gatekeeping" is a determination of whether the explanative theory works. . . . At the same time, however, *Daubert* states Rule 702 requires that an "expert's opinion will have a reliable basis in the knowledge and experience of his discipline," which is a reference to sufficient assurances that the explanative theory works.[198]

In fact, the Court's post-*Daubert* focus on scientific reliability has been misplaced.

The second term of art relied upon at times by the Court to construct its admissibility inquiry is "validity." In the context of scientific research, validity refers to the ability of a particular test to measure "what it purports to be measuring."[199] Reliability is just one component of validity and can be distinguished from scientific validity, which depends on considerations outside the test itself.[200] One commentator explained the concept of scientific validity

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[195] *See* Foster & Huber, *supra* n. 19, at 113 (simplifying scientific reliability into two separate components, sensitivity and specificity).

[196] *See id.* (explaining the concept of sensitivity through a hypothetical test designed to detect a specific infection in individuals).

[197] *See id.* at 113-14 (demonstrating the concept of specificity through the same hypothetical test).

[198] Graham, *supra* n. 8, at 336-37 (analyzing the *Daubert* Court's use of reliability as both an indicator of sound scientific methodology and a surrogate for the related term of scientific reliability).

[199] Foster & Huber, *supra* n. 19, at 146 (citation omitted) (defining the term "validity" within its scientific context). *See also Reference Manual on Scientific Evidence*, *supra* n.3, at 103 (describing a valid measuring instrument as one that measures what it is designed to measure).

[200] *See* Foster *& Huber*, *supra* n. 19, at 146 (articulating the relationship between scientific validity and external considerations).

as follows:

> "Validity" is also a term of art in science . . . [that] relate[s] to the connection between a theory or results of a particular study and the empirical world. . . . [Thus,] validity depends instead on the concordance between the theory by which one interprets data and how the inferences drawn from the data are going to be used.[201]

For example, while a polygraph may reliably measure certain physiological responses to stimuli, it is not considered valid as a lie detector unless "increases in pulse rate, blood pressure, and the like are well correlated with conscious deception."[202] Judges and lawyers assessing scientific validity should also keep in mind that, in common parlance, we often assume that theories are either valid or invalid. This is not true in science.

Scientific theories are almost never categorized as valid or invalid because they are rarely wholly accurate or wholly inaccurate explanations of the empirical world. Thus, we should also recognize that "'[v]alidity' in science is not a binary attribute, like pregnancy."[203] Scientific validity is better understood as a matter of degree rather than in absolute terms. If the court, therefore, determines that the scientific reliability of a theory is low, then its validity is suspect. A high level of reliability, on the other hand, does not necessarily establish the validity of a particular scientific theory or test.

When legal scholars and practitioners learn to use critical scientific terms of art with greater precision, they will quickly recognize that although a reliable test will produce similar data in subsequent experiments, a test that is valid for one purpose may not be valid for a different purpose. To paraphrase Justice Blackmun's example in *Daubert*, we might devise a *reliable* system for measuring the phases of the moon (that achieves consistent measurement results). Although the test will be *valid* for a study of ocean tides, it is not necessarily valid to measure the appearance of werewolves.[204]

To understand and use science, judges and lawyers need to know more than just that another experimenter can replicate a particular test. We need to know whether a particular test assists in understanding natural phenomena relevant to the resolution of a specific legal dispute.[205] We must also understand that

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[201] *Id.* at 143-46 (explaining the connection between scientific validity and observations concerning the empirical world).

[202] *Reference Manual on Scientific Evidence*, *supra* n. 3, at 103 (stating that a scientifically reliable test does not necessarily yield scientifically valid results).

[203] Foster & Huber, *supra* n. 19, at 17 (discussing the issue of scientific uncertainty and the limited ability of science to speak in terms of absolutes).

[204] *Daubert*, 509 U.S. at 591 (demonstrating through an example that the scientific validity of a test depends on the specific purpose for which it is used). *See also* David L. Faigman, *Legal Alchemy* 69 (W.H. Freeman 2000) (describing how science that might be very valuable in certain cases would be entirely irrelevant in others and that statistically significant research results might have no practical significance).

[205] An expert's own assertions can never establish either the reliability or the validity of

"[d]etermining the validity of a [particular scientific] theory is not the same as establishing its *truth*. . . ."[206] A valid theory is one that is logically reasoned and consistent with known observations. Its validity lasts only until the time when someone proves it wrong.[207]

C. *Misunderstanding Basic Scientific Methodology*

> *The legal system doesn't understand science . . . . I taught in law school for a year. Believe me, there's no science in there at all.*[208]

1. Why We Need to Understand Basic Scientific Methodology

In *Joiner*, Justice Breyer articulated the need for judges to understand basic scientific methodology in order to perform their roles as evidentiary gatekeepers.[209] Judges, and lawyers, must understand basic principles of scientific methodology to assess the validity of proposed scientific expert testimony.[210] *Daubert* originally required that the judge's focus "must be solely on principles and methodology, not on the conclusions that they

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any scientific theory. *See Joiner*, 522 U.S. at 146 (1997) (stating that in science, "conclusions and methodology are not entirely distinct from one another"). *See also Aldrige v. Goodyear Tire & Rubber Co.*, 34 F. Supp. 2d 1010, 1023 (D. Md. 1999) (discussing the need for independent validation of expert methodology).

[206] Foster & Huber, *supra* note 19, at 140 (emphasis added) (noting the temporal aspect of scientific validity and the chance that a theory accepted today might be quickly refuted tomorrow).

[207] *Id.*

[208] Gawande, *supra* n. 17, at 53 (quoting Gary Wells, Professor of Psychology at Iowa State University, a leading expert on eyewitness testimony and research).

[209] *Gen. Electric Co. v. Joiner*, 522 U.S. 136, 147-48 (1997) (Breyer, J., concurring). According to Justice Breyer:

> This [*Daubert*] requirement will sometimes ask judges to make subtle and sophisticated determinations about scientific methodology and its relation to the conclusions an expert witness seeks to offer—particularly when a case arises in an area where the science itself is tentative or uncertain, or where testimony about general risk levels in human beings or animals is offered to prove individual causation.

Id.

[210] Michael H. Gottesman, the attorney who argued on behalf of the *Daubert* plaintiffs before the Supreme Court, has suggested that "the prestige factor" potentially could influence an admissibility decision. Gottesman, *supra* n. 32, at 878. Gottesman reasons that:

> When a highly-qualified scientist is testifying within the specialized field to which she devotes her out-of-court career, her opinions should be admitted without further inquiry. [Under these circumstances] it would be truly arrogant for a judge, unschooled in the scientific discipline, to declare that the witness' life work is predicated on a methodology that is unreliable.

Id. This theory does not seem to have received support from any court or any other commentator.

generate."[211] As the cases interpreting *Daubert* make clear, the admissibility decision encompasses an evaluation of both the expert's methodology and the expert's application of those methods to the facts at issue.[212] For those nonscientists daunted by the task of analyzing the scientific methodology behind proffered evidence, Dr. Marcia Angell offers the following words of encouragement:

> The general approach [to scientific methodology] is easy to understand, because it is largely a matter of common sense. If nonscientists had a better feeling for the approach, they could gauge the probable strength of many scientific claims while knowing very little of the technical details on which they are based.[213]

Post-*Daubert* decisions from the U.S. Supreme Court support the idea that it is no longer appropriate for judges to focus solely on the soundness of an expert's methods, while leaving questions involving the application of these methods to the jury.[214] Four years after *Daubert*, the *Joiner* Court emphasized that the court must find some valid connection between the data that results from the application of the methodology and the conclusions drawn from that data. As the developing Supreme Court doctrine makes clear, judges must work to uncover mistakes in both the scientific methodology and its application to the particular facts of a case.[215] Errors in either task make the resulting conclusions less valid and therefore more likely to be inadmissible.[216]

Although it is somewhat difficult to provide a universally accepted definition of the scientific method, scientists generally agree that the following

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[211] *Daubert*, 509 U.S. at 595 (articulating the prominent role of scientific principles and methodology in an admissibility decision). The Court acknowledged only four years later that the task of separating principles, methodology, and conclusions may not be as simple as they had previously assumed. *See Joiner*, 522 U.S. at 146 (stating that conclusions and methodology are not entirely separate from each another in science).

[212] *See e.g. In re Paoli Railroad Yard PCB Litigation*, 35 F.3d 717, 745 (3d Cir. 1994) (assessing the plaintiffs' expert's methodologies, which included physical exams, laboratory tests, and differential diagnoses to conclude that the distinction between a methodology and its application is no longer viable).

[213] Angell, *supra* n. 18, at 91 (emphasizing that the easily accessible "broad outlines" of scientific methodology can provide non-scientists with enough information to make informed decisions).

[214] *See e.g. In re Paoli*, 35 F.3d at 745 (describing how after *Daubert*, ferreting out the misapplication of the methodology is no longer within the province of the jury).

[215] *See id.* (discussing the application of scientific methodologies to facts to yield an the expert's conclusion).

[216] "This is true whether the step completely changes a reliable methodology or merely misapplies that methodology." *In re Paoli*, 35 F.3d at 745 (explaining that the judiciary's gatekeeping role under *Daubert* requires a judge to reject evidence that is inadmissible because it has been misapplied to the facts of the case); *see also* Sanders, *supra* n. 21, at 372 (contending that often it is a combination of problems in the expert's testimony, rather than any one single flaw, that leads to the ultimate decision to exclude).

steps are components of scientific methodology:

> *Induction*: Forming a hypothesis by drawing general conclusions from existing data.
>
> *Deduction*: Making specific predictions based on the hypothesis.
>
> *Observation*: Gathering data, driven by the hypothesis that tells us what to look for in nature.
>
> *Verification*: Testing the predictions against further observations to confirm or falsify the initial hypothesis.[217]

The judicial inquiry should focus on the development of scientific hypotheses, the processes and mechanisms of testing hypotheses, the statistical significance of any research findings, and the development of scientific conclusions from those findings. Legal scholars and practitioners should also understand the importance and function of a null hypothesis and the standards for determining statistical significance. Although this basic level of comprehension will not make us scientists, it will help us begin to understand and evaluate proffered expert testimony.

Finally, we should recognize that an assumption of expert objectivity underlies the basic principles of scientific methodology. Over the years, philosophical questions of scientific objectivity have generated academic debate on the relationship between science and truth.[218] The persistent influence of the philosophy of science on the development of legal doctrine should not be ignored.[219]

In fact, *Daubert* and its progeny clearly reflect the considerable influence of certain well-known scientific philosophers. Most notably, the *Daubert* Court specifically referenced the highly influential work of scientific theorist Karl Popper.[220] Justice Blackmun's statement that "good science" encompasses theories and techniques that have survived "submission to the scrutiny of the scientific community"[221] reflects Popper's theory that valid scientific

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[217] Shermer, *supra* n. 18, at 19 (providing the basic elements of scientific thinking while cautioning the reader that scientists do not conduct research using this rigid framework of steps).

[218] *See e.g. Reference Manual on Scientific Evidence*, *supra* n. 3, at 69-75 (briefly reviewing ideas of scientific objectivity in the works of Bacon, Popper, and Kuhn).

[219] *See* Foster & Huber, *supra* n. 19, at 140 (acknowledging that "the connection between science and truth is as philosophically contentious as the nature of science itself").

[220] *See Daubert,* 509 U.S. at 593-94 (discussing the central role played by testability in determining whether a theory or technique qualifies as "scientific knowledge").

[221] *Id.* at 593 (describing the role of peer review and publication in the determination of scientific validity as increasing the probability of the detection of methodological flaws). The Court's understanding of scientific falsifiability was also likely influenced by the theories of Thomas Kuhn. *See* Thomas Kuhn, *The Structure of Scientific Revolutions* (2d ed., U. of Chicago Press 1970). In this seminal book, Kuhn described how experimental inconsistencies and contradictions do not immediately challenge the existing paradigm of

propositions must be framed so that contradiction by other scientists is possible.[222] By referencing Popper's work in *Daubert*, the Supreme Court placed special emphasis on Popper's belief that "[t]he criterion of the scientific status of a theory is its falsifiability, or refutability, or testability."[223] Thus, according to Popper and the views adopted by the *Daubert* Court, scientific theories that have withstood the criticism of other scientists should be adjudged more reliable, more scientifically valid, and therefore more likely to be admitted in court, than those that cannot be tested or have been discredited by further experimentation.[224]

The assumption of scientific objectivity also raises questions involving the effect of the human scientist.[225] The objectivity of any expert, or test results relied upon by any expert, can be contaminated when hidden incentives influence the collection and/or interpretation of scientific data.[226] Critiques of objectivity extend far beyond the exposure of biased experts, however, as theories abound regarding the potential influence of culture,[227] race, gender,[228] or experience, for example, on human scientists. These theories, while intriguing and sometimes provocative, should not be understood to prove that science is incapable of assessing the validity of alternative hypotheses.[229] The level of objectivity required for science to inform our understanding of the empirical world is not absolute and critiques based upon relativism can never excuse judicial passivity on questions involving scientific evidence.

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scientific knowledge but in the aggregate can break with the paradigm and quickly bring science in a new direction. Kuhn believes that scientific revolutions are "the tradition-shattering complements to the tradition-bound activity of normal science." *Id.* at 6.

222 *See* Foster & Huber, *supra* n. 19, at 19 (discussing the central role of falsifiability in Popper's theories. In a 1989 article analyzing the relevance of social science to legal decision-making, Professor David Faigman discussed the importance of the falsifiability standard to social science research that claims to be based upon objective knowledge. *See* David L. Faigman, *To Have and Have Not: Assessing the Value of Social Science to the Law as Science and Policy*, 38 Emory L.J. 1005, 1015 (1989) (stating that "[f]alsifiability or testability represents the line of demarcation between science and pseudo-science").

223 *Daubert*, 509 U.S. at 593 (citation omitted) (articulating Popper's statement on the importance of scientific falsifiability).

224 *See id.* (discussing Popper's view of scientific falsifiability).

225 *See e.g.* L. Laudan, *Science and Values* (Univ. of Cal. Press 1984).

226 *See supra* n. 17 (discussing investigative reporting that documented conflicts of interest between interventional cardiologists and medical device companies).

227 *See* Angell, *supra* n. 18, at 179 (discussing various multicultural critiques of science).

228 *See id.* at 180-81 (discussing feminist critiques of science).

229 The fact that science can yield uncertain results does not mean that "'truth' is relative, as a pernicious kind of postmodernism maintains." Foster & Huber, *supra* n. 19, at 16-17. "Rather, it is to say that science has limited ability to answer questions of great social importance." *Id.*

2. How to Improve Our Understanding of Basic Scientific Methodology

To begin to understand the difference between the scientific and legal processes, imagine what would happen if we attempted to import scientific methods and processes into the judicial system. For example, if scientific principles were applied to the criminal trial setting, a defendant could never be acquitted unless the defense attorney could provide an explanation for all of the defendant's actions and activities that was superior to the explanation provided by the prosecutor. Having met this burden, the defense attorney would then be required to explain away all possibly relevant events implicating her client that the prosecutor did not discuss. Communications between the defense attorney and her client and all materials relating to defense investigations or strategies would be discussed in open court and scrutinized by the prosecutor, the judge, and the jury. The jury would be comprised of experts in relevant fields. Jurors would be allowed to discuss the proceedings throughout, perform their own investigations, ask questions of all participants, call their own witnesses, and hire their own experts. Litigants would have an unlimited amount of time to present their cases and the jurors could arrive at their decision whenever they chose. Finally, the jurors' verdict would be expressed as an estimate, quantified in terms of statistical probabilities, of the increased risk that a person with characteristics similar to the defendant under similar circumstance, could have committed the charged crime.

The imaginary scientific courtroom is intended to highlight the vast differences between legal and scientific methodologies. "In science, the evidence leads to the conclusion; in the courtroom, the expert's conclusion comes first and becomes the legal evidence. Not surprisingly, the answers yielded by these two approaches may differ greatly."[230] According to Justice Breyer,

> the most obvious . . . [problem that judges and lawyers have with scientific evidence] is that most judges lack the scientific training that might facilitate the evaluation of scientific claims or the evaluation of expert witnesses who make such claims. Judges are typically generalists, dealing with cases that can vary widely in subject matter. Our primary objective is usually process-related: seeing that a decision is reached fairly and in a timely way.[231]

In light of the interdisciplinary procedural differences in procedures, a first step toward improving the successful integration of science into the courtroom is that we familiarize ourselves with the scientific process.[232] A general

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[230] Angell, *supra* n. 18, at 179-80 (explaining the fundamental differences between science and the courtroom).

[231] *Reference Manual on Scientific Evidence, supra* n. 3, at 4.

[232] The federal courts have begun to specifically recognize this obligation. *See e.g. Braun v. Lorillard, Inc.*, 84 F.3d 230, 235 (7th Cir. 1996) (agreeing with *Daubert* that a familiarity with the scientific process will allow a court to question an expert's departure

understanding of the scientific process will allow judges and lawyers to differentiate between pseudoscientific claims and valid scientific claims.[233]

Science strives to explain, predict, understand, and control natural phenomena.[234] These goals are achieved through the "cumulative growth of a system of knowledge over time, in which useful features are retained and nonuseful features are abandoned, based on the rejection or confirmation of testable knowledge."[235] The study of science is generally progressive.[236] To a certain extent, it also self-corrects as it continues to be refined based on new observations and interpretations. Scientists facilitate this process through the presentation, debate, and testing of new ideas.

To begin to comprehend how scientists approach the process of acquiring knowledge, we should start with how scientists form the questions they will explore. Most scientists are interested in finding patterns, particularly patterns attributable to causal relationships.[237] That interest develops into a hypothesis Although often phrased as a conclusion, each hypothesis is a question that presupposes a pattern and that must be explored through experiments designed to support or discredit the hypothesis itself.[238]

Legal scholars and practitioners should note that mistakes that will diminish the predictive value of a scientific study can be made as early as the scientist's formulation of a hypothesis.

> If, for example, researchers want to know whether breast implants increase the risk of connective tissue disease, they need to choose some

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from well-accepted scientific practices).

[233] Angell, *supra* n. 18, at 91. ("Not knowing the broad contours of the process feeds the false belief that medical [and other scientific] research is somehow too complex to be understood by nonscientists. This may be true of the details of any given study, but it is not true of the broad outlines.").

[234] Scientific laws describe repeating natural phenomena, while pseudoscientific claims are idiosyncratic. One example of a pseudoscientific belief that has been widely disseminated in the popular media is the purported link between childhood vaccines and autism. Although numerous class action lawsuits have been filed throughout the U.S. against vaccine manufacturers, the epidemiological studies performed to date show no link between vaccines and autism. Sandra Blakeslee, *Panel Cautions Against Mercury Preservative*, 151 N.Y. Times A16 (October 2, 2001). Childhood vaccines save children's' lives and are generally considered safe. In fact, less than one child in one million will experience any serious side effect as a result of immunization. Despite these statistics, "[s]ome critics ignore the public health science and promote policies that jeopardize the protection provided by childhood vaccines." Patricia Nolan, Providence Journal B9 (May 21, 2000) (Ms. Nolan is the Director of the Rhode Island Department of Health).

[235] Shermer, *supra* n. 18, at 31 (emphasizing the unique cumulative nature of science).

[236] *Id.* (explaining the progressivity of science).

[237] David Knoke & George W. Bohrnstedt, *Basic Social Statistics* 7 (1991).

[238] Even conclusions in science are regarded as questions. *See* Jacob Bronowski, *The Ascent of Man* 21 (Little, Brown & Co. 1972) (quoting Niels Bohr) ("Every sentence that I utter should be regarded not as an assertion, but as a question.").

> suitable evidence of connective tissue disease and determine whether it is more common in women with implants than in women without implants. It would not be adequate to study whether women with implants are fatigued because fatigue is not specifically enough related to connective tissue disease and its presence or absence would not directly address the question.[239]

To avoid such mistakes at the outset of the scientific process, scientists propose ideas and make informed guesses about patterns based on their own observations or the work of other scientists. These patterns are frequently referred to as associations or relationships between variables.[240] The initial hypothesis, developed from these observations, may link certain variables and/or speculate about causation, in an attempt to understand, explain, or predict some natural phenomena.[241]

An example taken from recent medical news involves the hypothesis that exposing postmenopausal women to increased levels of estrogen reduces their risk of heart disease.[242] This hypothesis assumed a causal relationship between two variables. The assumption is that a change in one variable, often referred to as the independent variable[243] (i.e., the increased estrogen), creates a predictable change in a second variable, often referred to as the "dependent variable" (i.e., the reduction in the rate of heart disease).[244]

A scientific study based on any hypothesis will test the hypothesis against a "null hypothesis" of no causal effect. The researcher will try to prove the null hypothesis wrong. The null hypothesis is:

> the assumption that the phenomenon they are studying does not cause the effect they expect. In other words, the standard method of science is to presume "innocence" and only with strong proof reject that

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239 Angell, *supra* n. 18, at 92 (noting the importance of framing a hypothesis that fits closely with the observations in the study).

240 A "variable" can be defined as "an observable characteristic of an object or event that can be described according to some well-defined classification or measurement scheme." Frederick Williams, *Reasoning with Statistics: How to Read Quantitative Research* 11 (4th ed. 1992).

241 *See generally* E. Bright Wilson, Jr., *An Introduction to Scientific Research* (McGraw-Hill Book Company, Inc. 1952) (describing the goals and methods of conducting scientific research).

242 *See* Lindsey Tanner, *Replacement Hormones: Study of 27,000 Women Examines Value of Supplements*, Chi. Trib. 7 (September 12, 2000) (examining the value of the hormone supplement synthetic estrogen).

243 "Independent variables" are defined as "variables that represent the causes" and they "also are called factors or explanatory variables." *Reference Manual on Scientific Evidence*, *supra* n. 3, at 92.

244 Knoke & Bohrnstedt, *supra* n. 237, at 7. A "dependent variable" can also be defined as a "variable that characterizes the effect . . . since it may depend on the causes; dependent variables are also called response variables." *Reference Manual on Scientific Evidence*, *supra* n. 3, at 92 (defining elements of a scientific hypothesis).

presumption.[245]

It should be noted that no amount of studying and testing of a sample from a much larger population can prove conclusively that the null hypothesis is wrong. It is simply impossible to use this standard methodology to prove a negative. By contrast, one can very easily prove with 100% certainty that a null hypothesis is wrong (or false) when the entire population comprises the sample. For example, if I wished to study the relationship between decapitation and death, in a population of ten "decapitees," I could not prove the absolute falsity of a null hypothesis claiming that decapitation does not cause death if I studied a sample consisting of eight of the ten "decapitees," although the power of my statistical analysis would still be extremely high. However, if I studied all ten (i.e., the sample *is* the entire population), then I could quite easily prove with complete certainty that the null hypothesis (decapitation does not cause death) is false for *this population.* In the ordinary circumstance of studying a sample portion of a population, each study that fails to support the hypothesis makes the null hypothesis more likely. Conversely, if extensive experimentation continues to support the hypothesis, a scientist can amass enough evidence to make the hypothesis so probable that it is considered true for all practical purposes.[246]

When a scientist sets out to explore a preliminary hypothesis, his analysis will be guided by the particular methodologies, i.e., the practices, procedures, and protocols, that are accepted as fundamental to his discipline. A scientist uses these methodologies to guide her research as she proposes, tests, and refines various hypotheses and theories. For example, one methodology common to all scientific disciplines is the requirement of accurate and detailed record keeping. This method enables future scientists to assess the validity of the original experiment through peer review and experiment replication.[247] As part of their record keeping, scientists should include both the experimental results that support their hypothesis and those that do not.

After formulating the hypothesis and developing the study, researchers will

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[245] Faigman, *supra* n. 204, at 67 (defining the null hypothesis).

[246] Angell, *supra* n. 18, at 97 (noting also that probability and uncertainty are to some degree inherent to scientific research).

[247] *Daubert* emphasized the importance of peer review in the judicial evaluation of scientific evidence. *Daubert v. Merrell Dow Pharm., Inc.*, 509 U.S. 579, 594 (1993). This is based on the assumption that peer review has the potential to stop the progress of unreliable scientific testing of invalid scientific theories. The most widely publicized example of the power of peer review was the public announcement of successful cold fusion experimentation, which was quickly followed by resounding refutation through extensive peer review. The fact that no scientist has ever successfully replicated cold fusion experiments shows how even well-respected scientists make mistakes. The cold fusion debacle also demonstrated how peer review can correct these mistakes. *See generally* Gary Taubes, *Bad Science: The Short Life and Weird Times of Cold Fusion* (Random House 1993) (describing cold fusion research, its "discovery" and public announcement, and the refutation that followed).

begin to amass data.[248] Data collection generally occurs through the accumulation of three components: (1) anecdotal evidence, (2) observational studies, and/or (3) controlled experimentation. Of the three methods of data collection, controlled experiments are widely considered the best method for testing theories of causation. All three methods, however, are worth considering.

The first method of data collection listed above, the gathering of anecdotal evidence, requires the scientist to keep a record of events that follow one another. Reports of anecdotal evidence usually are obtained haphazardly or selectively and do not sufficiently demonstrate that the first event causes the second. As a result, anecdotal evidence can be suggestive but misleading.[249]

The second method of data collection, observational studies, generally occurs in the context of medical testing. Observational studies monitor what happens to those who have already been exposed to the variable. Two useful forms of observational studies are "cohort" studies and "case control" studies.[250] Cohort studies start with two similar groups of people, one exposed to the variable and one unexposed. Normally in a cohort study, none of the participants would have, for example, the disease being studied at the time the study began. "Case-control" studies begin with two groups of similar people, one comprised of people who already have the disease and one comprised of people who do not. In either cohort or case control studies, the subjects of the study are monitored over time and their medical conditions are compared. Conclusions about the effect of exposure are then extrapolated from the comparison data.

The third, and most reliable, method of data collection, controlled experiments, generally tests and measures[251] the consequences of exposing a group of test subjects. The research protocol intentionally exposes one group to a particular variable and does not expose the other group.[252] The best method for determining whether a particular variable is a risk factor for a specific disease is to find as large a group as possible of similar test subjects and expose half of the group to the risk factor. The experimenter would then follow both groups through time in order to compare the effects of exposure to the risk factor with non-exposure.

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[248] Angell, *supra* n. 18, at 93 ("Collecting data means measuring or counting something.").

[249] *Reference Manual on Scientific Evidence, supra* n. 3.

[250] Angell, *supra* n. 18, at 99-100 (discussing epidemiological studies).

[251] A "measurement" in the context of statistical research is "a scheme for the assignment of numbers or symbols to specify different characteristics of a variable." Williams, *supra* n. 240, at 11 (defining "measurement").

[252] The most reliable method for conducting controlled experimentation requires that neither the experimenter nor the subjects know whether the subjects have been exposed to the tested variable. This type of experiment is generally referred to as "double blind testing."

All three data collection methods are limited by the fact that very few risk factors inevitably cause a particular outcome. More often, a successful preliminary finding may identify a risk factor that is associated with a particular disease. The association of a risk factor with a particular disease, however, does not in itself speak to the causal relationship between the disease and the risk factor. Association simply means that the data show that the risk factor and disease are present. Indeed, even when the data indicate an association, scientists may be unable to determine what, if any, role this risk factor plays in causing the disease.[253]

Recent breast implant litigation illustrates the legal problems that arise when association is mistaken for causation. In the early 1990s, the media and numerous plaintiffs' attorneys brought to public attention a possible association between silicone breast implants and connective tissue disease, giving legal imprimatur to the causal connection between the implants and the disease.[254] In December 1991, a federal jury in San Francisco awarded a single plaintiff $7.34 million dollars; five months later, the FDA banned silicone breast implants.[255] These verdicts led the public to assume that silicone breast implants cause connective tissue disease.[256] Such a connection has never been shown. In fact, "none of the epidemiological studies has been able to demonstrate a clear link between breast implants and connective tissue disease or suggestive symptoms."[257] Silicone breast implants might have had a different fate if the court had marked a clearer distinction between association and causation in considering the effect of silicone as an independent variable on the human, the dependent variable.

Once the association between a risk factor and a possible outcome has been identified, scientists begin the process of quantifying that risk. "Relative risk" is the term used to describe the strength of association between a risk factor and a particular outcome.[258] In medical research, for example, relative risk is "the ratio of the incidence of the disease in an exposed population to that in an unexposed population."[259] Generally, legitimate theories of scientific causation must be based on strong link between independent and dependent

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[253] "It is a canon of science that association never proves causation." Foster & Huber, *supra* n. 19, at 151 (distinguishing between "association" and "causation" in scientific studies).

[254] *See* Angell, *supra* n. 18, at 50-57 (commenting on the events leading up to the FDA ban on silicone breast implants).

[255] *See* W. Carlsen, *Jury Awards $7.3 Million in Implant Case*, San Francisco Chronicle A13 (Dec. 14, 1991); Angell, *supra* n. 18, at 50-57.

[256] *Id.*

[257] *Id.* at 57 (showing that extensive research weakened the assumed causal relationship between breast implants and connective tissue disease).

[258] Foster & Huber, *supra* n. 19, at 78 (evaluating the statistical significance of a risk factor in medical tests).

[259] *Id.*

variables. As the strength of the association increases, there is more support for finding a causal connection. For example, "cigarette smoking is so strong a risk factor for lung cancer that we are justified in saying it 'causes' cancer, even though we do not yet know exactly how it does so."[260]

As experimentation continues, the scientist will constantly reevaluate her initial findings. Experimentation helps the scientist identify the strengths and weaknesses of her initial hypothesis. Scientific testing may end if researchers have collected data that are statistically significant. Statistical significance means that the groups of data gathered from testing the hypothesis against the null hypothesis "differ from each other at a predetermined level of confidence."[261] In other words, statistically significant data shows that "the association is unlikely to be due to chance."[262]

The final steps in any empirical research involve the analysis of data and development of conclusions. Mistakes in data analysis or in the extrapolation of conclusions can invalidate any scientific study. When evaluating science, we should be aware of the following problems. First, a statistical association reported in a study may be a real cause-effect relationship, a sampling error, or a result of a flaw in the researcher's methodology. Second, "[i]nterpreting a study is perilous because of the strong temptation to reach conclusions that are more encompassing than the evidence will support."[263] Third, even if a study is persuasive under the conditions of an experiment, "extrapolat[ing] from the conditions of a study to more general circumstances always raises questions."[264]

During and after the empirical research, other scientists working in the field may further refine the hypothesis. [265] At some point scientists will begin to

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[260] Angell, *supra* n. 18, at 98 (noting also that very few non-smokers get lung cancer). Most risk factors, or independent variables, do not rise to the level of strength portrayed in the cigarette smoking example. It is sometimes impossible to determine whether a particular risk factor actually contributes to causing a disease or is simply associated with a disease. Determining the strength of association, however, does not necessarily follow the identification of an independent variable known as a risk factor in medical research. In fact, identifying an independent variable sometimes depends on how strongly that variable associates with a dependent variable. The very process that determines the association of strength can sometimes be part of the identifying process. *Id.*

[261] Beecher-Monas, *supra* n. 45, at 1095 (explaining probabilistic evaluation in determining causation). Confidence levels are measurements of the probability that study results from a given sample will be correct for the relevant population from which the sample was drawn. Foster & Huber, *supra* n. 19 at 77.

[262] *Id.* (illustrating the way scientists conclude there is an association between variables).

[263] *Id.* at 94 (warning against the tendency to draw overly broad conclusions from data).

[264] *Reference Manual on Scientific Evidence*, *supra* n. 3, at 96 (explaining the uncertainty in generalizing scientific results to broader circumstances).

[265] Cumulative scientific knowledge is gained by the processes of observation, experimentation, quantification, corroboration, and correction by other scientists. *See e.g.* Beecher-Monas, *supra* n. 45, at 1095 (observing that "scientists recognize that multiple

share results and compare testing mechanisms. Disparities in experimental conditions and their potential effects on scientific outcomes may be compared and contrasted. A hypothesis that has yielded statistically significant results should then be incorporated back into the methodologies that will govern future work in this discipline. In this way, the methodologies controlling most scientific disciplines are constantly enhanced and refined. Understanding scientific methodologies should help judges and lawyers identify the proposed expert testimony that is based on nonscientific or pseudoscientific theories.[266]As part of the admissibility inquiry, legitimate experts should be able to identify and articulate for the court the current methodologies employed by experts in the field to validate tested hypotheses.

D. *Misunderstanding Statistics*

1. Why We Need to Understand Basic Principles of Statistics

Legal scholars and practitioners who must assess the quality of scientific evidence must also acquire a basic understanding of core statistical concepts. Because statistical reasoning underlies all empirical research, we must become familiar with statistics and probabilistic reasoning to prepare for complex scientific or mathematical issues.[267] Legal scholars and practitioners, however, are often confounded by the principles of statistical analysis, risk assessment, probabilistic attribution, and attendant mathematical jargon. This confusion persists despite the fact that "statistical analysis and probabilistic thinking are key to understanding the validity of scientific studies.... [and] probabilistic reasoning is the foundation of modern science."[268] Confusion over statistics can also arise in court when a discomfort with science encourages the development of vague measurements that further obfuscate the appropriate inquiry. For example, questions couched in imprecise but widely used terms such as "a reasonable degree of medical certainty," are often susceptible to more accurate quantification.

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confirmatory studies in different disciplines reinforce the conclusions of a single study").

[266] Faigman, *supra* n. 204, at 4 (identifying handwriting identification as an example of a discipline that does not use rigorous scientific methods.) Faigman supports this conclusion by citing the "lack of empirical validation and failure to conduct proficiency testing, the failure to 'blind' testers to expected results, and the overwhelming subjective component" in handwriting analysis methods. *Id.*

[267] *Id.* at 70-71.

[268] Beecher-Monas, *supra* n. 45, at 1069. Legal scholars and practitioners may not be the only ones whom statistics confuse. A 1988 article published in the British Journal of Surgery found that 39% of the articles surveyed contained serious statistical errors that justified rejection of the article. *See* Foster & Huber, *supra* n. 19, at 148(discussing statistics-related problems faced by scientists). As one commentator notes, "[j]ust because a study has used statistics is no guarantee of its worth. In fact, statistics can be misused either intentionally or unwittingly, and it is not difficult to locate quantitative studies where statistics were not really needed at all." Williams, *supra* n. 240, at 3.

As a preliminary matter, experts in all aspects of science testify to probabilities or statistical measurements in practice. For that reason, judges and lawyers need to decide in advance how they will approach the job of understanding and assessing this information at trial. To avoid lengthy courtroom debate, much of this evaluation should be done pretrial. Once trial has begun, the Federal Judicial Center has advanced the following alternative to the traditional sequential presentation of experts:

> [W]hen the reports of witnesses go together, the judge might allow their presentations to be combined and the witnesses to be questioned as a panel rather than sequentially. More narrative testimony might be allowed, and the expert might be permitted to give a brief tutorial on statistics as a preliminary to some testimony. Instead of allowing the parties to present their experts in the midst of all the other evidence, the judge might call for the experts for opposing sides to testify at about the same time.[269]

This structure has the advantage of enabling jurors to have complex testimony from one side fresh in their minds when they listen to testimony from an opponent's expert. Confusion might also be alleviated if experts can relate the areas of agreement and address their difference to the jury through a controlled dialogue

2. How to Improve Our Understanding of Basic Statistics

a. *Legal Practitioners and Scholars Probably Know More About Statistical Analysis Than They Realize*

Those unfamiliar with statistics should bear in mind that statistics are simply mathematical quantifications of risk, analogous to the bases for many other legal decisions.[270] Although a primer on basic statistical concepts is beyond the scope of this Article, even novices should quickly recognize that they are more familiar with basic statistical concepts than they realize.[271] Many of the questions routinely addressed by a court involve an explicit or implicit statistical assessment.[272]

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[269] *Reference Manual on Scientific Evidence, supra* n. 3, at 89.

[270] *See* Stephen E. Feinberg, Samuel H. Krislov & Miron L. Straf, *Understanding and Evaluating Statistical Evidence in Litigation,* 36 Jurimetrics 1, 2 (1995).

[271] Legal scholars and practitioners can use their everyday experience to understand fundamental principles of statistics. For example, common sense would tell us that a valid comparison of student performance between two separate law school classes requires that we know more than just the mean (i.e., average) student grade. A meaningful comparison requires that we also know the median (the middle value in the distribution, half the grades are below this number and half above) and the distribution of grades along the grading scale.

[272] Feinberg et al., *supra* n. 270, at 3 (noting that statistical evidence is introduced to a court implicitly through reasoned judgments and explicitly through testimony on scientific data).

In fact, at some level of abstraction, all decisions made by the judge during a trial are probabilistic. For example, determining the admissibility of evidence at trial requires that lawyers argue, and judges decide, the likelihood that the evidence, if admitted, will make some fact of consequence more or less likely.[273] The admissibility decision also requires the judge to assess the degree of risk of unfair prejudice, confusion, delay, and needless accumulation of evidence, that could result from admitting this evidence.[274] As the trial progresses, judges must make numerous legal decisions that contain implicit assumptions involving risks and probabilities. Legal scholars and practitioners might therefore alleviate their discomfort with statistical concepts by recognizing that statistics are simply a mathematical representation of the type of legal assessments, or balancing of probabilities, common to legal practice and judicial decision-making.

In addition to recognizing that litigation is full of probabilistic decision-making, legal scholars and practitioners should anticipate that they will be required to evaluate statistical data to assess the "predictive value" of proffered test results and theories.

> [A] test that has a high predictive value is likely to identify individuals correctly; it is trustworthy. Predictive value clearly depends on both the qualities of the test itself (sensitivity and specificity) and the base rate. The predictive value is the ratio of true positives (individuals who test positive and who really are infected, for example) to the total number of people who test positive, correctly or incorrectly.[275]

In practice, litigants advance statistical analyses measuring the predictive value of scientific tests or theories in a variety of situations. An opposing party may use statistical information to dispute any or all of the components of the methodological process of scientific evidence proffered by the other side. Parties may sometimes agree on a particular hypothesis, acknowledge that an experiment is well designed, and conclude that the data collection was accurate while disagreeing about the proponent's estimate of statistical significance of the test results. Thus, legal practitioners and scholars may require a basic understanding of statistics to comprehend how the opinions of two experts actually differ.[276] Such an understanding will decrease the possibility that factfinders will base decisions on immaterial facts.[277] Confusion over statistics or mathematics should not lead judges and lawyers to lose sight of certain

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[273] Fed. R. Evid. 401 (2000) (defining the term "relevant evidence").

[274] Fed. R. Evid. 403 (2000) (allowing exclusion of evidence if the danger of unfair prejudice substantially outweighs the probative value).

[275] Foster & Huber, *supra* n. 19, at 115 (describing how Bayes' theorem defines predictive value).

[276] *See* Feinberg et al., *supra* n. 270, at 7 (citing concern over a factfinder's ability to resolve differences between conflicting expert testimony).

[277] *See id.* at 9 (remarking that judges without a solid understanding of statistics may base decisions on irrelevant factors).

unassailable truths.

One basic truth is that the predictive value of any experiment will increase as the base rate for the tested condition rises.[278] In other words, experiments that claim to identify conditions that we know from reliable data are common in the relevant population often yield correct results.[279] For example, if a test shows that a 30-year-old adult received an MMR (Measles, Mumps and Rubella) vaccination, and if we know that the vast majority of 30-year-old adults have received this vaccine, it is likely that the test result is valid.[280] By contrast, even well-designed tests are more likely to yield incorrect results when they search for rare events.[281] For this reason, if judges and lawyers assess the base rate as a preliminary step, they can place statistical data in context and allow an inference of likelihood and probability. These examples show us that we should not abandon common sense in the face of confusing statistical jargon.

b. *Core Principles of Statistical Analysis*

Understanding the statistical inferences made from scientific evidence requires knowledge of how empirical tests are designed, data is collected, and results are interpreted.[282] Statistical research may focus on single variables or multiple variables. Statistical analyses applied to single variables are commonly referred to as descriptive statistics.[283] Descriptive statistics, gathered through observation, provide numerical detail designed to enhance our understanding of the properties of a variable, e.g., the average rainfall, interest rates, populations, or proportions of 18-year-olds attending college.[284] Most of the statistical research encountered by legal practitioners and scholars, however, assesses the impact of multiple variables. Research involving multiple variables involves inferential statistics, which provides mathematical tools for exploring the relationship between two or more variables.[285] The relationship between the variables may simply be observed and recorded, or

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[278] *See* Foster & Huber, *supra* n. 19, at 114 (asserting that the predictive value of a test depends on the prevalence of the condition in the population and noting that *prevalence* is also referred to as the *base rate* of the condition).

[279] *See id.* at 114 (commenting that tests used to diagnose common conditions have a higher probability of accuracy).

[280] *See id.* (offering a parallel example).

[281] *See id.* at 116 (explaining that a positive result for HIV (the Human Immunodeficiency Virus) in a population based on random selection is unreliable due to the low base rate).

[282] *See* Feinberg et al., *supra* n. 270, at 12 (stating that courts must have basic understanding of models and assumptions to understand statistical evidence).

[283] Descriptive statistics describe the "calculated values that represent certain overall characteristics of a body of data." Williams, *supra* n. 240, at 13.

[284] Knoke & Bohrnstedt, *supra* n. 237, at 11.

[285] *Id.*

the researcher may manipulate the variables.[286]

Only a statistically significant relationship between variables helps to determine causation. Most scientists define "statistically significant" test results as results that have a 5% or smaller chance of being random.[287] This requirement corresponds to a *p* value ('*p*' derives from 'probability') of 0.05 and a confidence level of 95%.[288] A *p* value of 0.05 means that "there is a probability of less than 5 percent—according to the statistical tests used—that the investigators would have recorded a difference . . . [that] large in the sample if the populations from which the [sample] groups were drawn were the same with respect to the properties being compared."[289] A *p*-value factor of 0.05 does not mean that the hypothesis has a 95% chance of being correct. It means only that the result observed has a 95% chance of being valid.

Legal practitioners and scholars who assess statistical significance should also recognize the difference between the measurement of the size of the scientific effect and the measurement of the degree of certainty. For instance, a study might conclude that exposure to chemical "x" results in a 10% increased risk for developing a particular disease. This result measures the size of the scientific effect. However, this same study might have a *p*-factor of 0.02 indicating a 98% certainty that the results were not random.

Although existing legal doctrine does not require the judge to incorporate the scientific standard of statistical significance into the admissibility determination, basic comprehension of core statistical concepts has at least three distinct advantages for the court. First, the judge will be more comfortable assessing the validity of proffered scientific evidence. Second, this approach has the advantage of providing the court with a high level of certainty.[290] Finally, judges who understand how scientists measure test results are less likely to confuse different scientific measurements or the legal and scientific burdens of proof.[291]

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[286] Williams, *supra* n. 240, at 15 (contrasting descriptive and experimental methods).

[287] Foster & Huber, *supra* n. 19, at 77 (defining "statistical significance").

[288] Feinberg et al., *supra* n. 270, at 22 (describing statistical significance as set by convention at a confidence level of 95%). Scientists generally require a confidence level of 95% before they consider results scientifically significant. *See* Foster & Huber, *supra* n. 19, at 78 (explaining that scientists choose small *p* values so they do not falsely identify an effect). For a discussion of the kinds of uncertainty in the statistical evidence that appears in toxic tort litigation, see Troyen A. Brennan, *Helping Courts with Toxic Torts: Some Proposals Regarding Alternative Methods for Preventing and Assessing Scientific Evidence in Common Law Courts*, 51 U. Pitt. L. Rev. 1, 24 (1990).

[289] Foster & Huber, *supra* n. 19, at 77 (explaining the meaning of a *p* value set at 0.05).

[290] *See* Feinberg et al., *supra* n. 270, at 7 (arguing that courts have welcomed statistical evidence to establish the cause-and-effect relationship). Reliance on the standard of statistical significance by judges predates *Daubert*. *See e.g. Brock v. Merrell Dow Pharm., Inc.*, 874 F.2d 307, 312 (5th Cir. 1989) (citing plaintiff's failure to provide the court with a study demonstrating statistical significance as reason for judgment in defendant's favor).

[291] *See* Feinberg et al., supra n. 270, at 7 (contending that understanding scientific

c. *Recognizing the Importance of Error Rates*

No observation, test, or study is ever infallible. Competent statistical analysis requires some exploration into, and thus an understanding of, the related issue of error rates.[292] In fact, *Daubert* instructs judges and lawyers to consider error rates when determining the admissibility of proposed scientific evidence.[293]

To understand scientific error rates, we must familiarize ourselves with false negative, false positive, and sampling errors. A false negative error occurs if the experimenter misses a real effect; a false positive error results when the experimenter perceives an effect that did not occur.[294] The rates of false positives and false negatives affect the accuracy of the test.[295] Second, sampling error may also increase when an experimenter extrapolates the results of a small sample of a population to a much larger group.[296] Findings that do not rise to the level of statistical significance do not necessarily provide evidence about the validity of the hypothesis. A negative or inconclusive result means only that the experiment failed to identify positive results.[297]

Problems with error rate calculations most often arise in the context of a controversy regarding the accuracy of the expert's risk assessment.[298] This controversy often accompanies studies claiming that a substance is causally connected to the development of a disease, such as cancer, in highly exposed animals, while epidemiological data concerning humans are either negative or mixed.[299] When human studies fail to demonstrate a statistically significant

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evidence will decrease the risk of decisions based on irrelevancies); *see e.g. In re Joint Asbestos Litig.*, 52 F.3d 1124, 1128-29 (2d Cir. 1995) (confusing the statistical significance with the degree of risk).

[292] Scientists can learn from their failures as well as their successes. Mistakes are generally considered to be a normal part of the scientific process. *See e.g.* Park, *supra* n. 15, at 9 ("Error is a normal part of science and uncovering flaws in scientific observation or reasoning is the everyday wok of scientists"). Moreover, hypotheses that have been disproved through experimentation and analysis can also bring scientists closer to the truth. Results of unsuccessful attempts to validate hypotheses are often published so that other scientists can learn from the results.

[293] *Daubert*, 509 U.S. at 594 .

[294] Foster & Huber, *supra* n. 19, at 75 (defining the "accuracy of the test" as "the frequency with which the test will produce positive results when given known positive samples").

[295] *Id.* at 76.

[296] *Id.* (noting that an investigator must choose parameters carefully since false positives, as well as false negatives, affect accuracy and result in sampling error).

[297] *Id.* (citing the example of epidemiological studies).

[298] *Id.* Risk assessment is "the identification and quantification of risks." *Id.*

[299] *Id.* For an excellent discussion of cases involving animal studies, *see* Capra, *supra* n. 47, at 716-17. Capra suggests that the federal courts have taken a type of "best evidence" approach to animal studies. This means that if valid human epidemiological studies are available, then animal studies are often rejected. By contrast, if the epidemiological data do

increased risk of cancer, it is unclear whether the study results are negative (there was no effect) or inconclusive (the effect did not reach the level of statistical significance, the test was flawed, etc.).[300] This problem can be compounded when scientists or the general public mischaracterize or misunderstand inadequate study results as disproving a hypothesis.[301]

III. IDENTIFYING COMPLEX SCIENTIFIC QUESTIONS AND CRAFTING CREATIVE INTERDISCIPLINARY SOLUTIONS

It would be overly simplistic to assume that legal scholars and practitioners who manage to both master the requirements of *Kumho* and acquire a basic understanding of scientific jargon, methods, and statistical concepts will be equipped to tackle every question involving scientific evidence. Some cases are too technical for nonscientist judges and lawyers to comprehend fully, and science is so broad that methodologies vary significantly between different scientific disciplines. Even Justice Breyer has conceded that "judges are not scientists and do not have the scientific training that can facilitate the making of such [scientific] decisions."[302] However, legal practitioners and scholars who increase their scientific sophistication will also improve their ability to identify scientific issues that require a creative, interdisciplinary approach for resolution.

Judges have numerous options for obtaining outside assistance with complex scientific or technical questions.

> [A]s cases presenting significant science-related issues have increased in number, judges have increasingly found in the Rules of Evidence and Civil Procedure ways to help them overcome the inherent difficulty of making determinations about complicated scientific or otherwise technical evidence. Among these techniques are an increased use of Rule 16's pretrial conference authority to narrow the scientific issues in dispute, pretrial hearings where potential experts are subject to examination by the court, and the appointment of special masters and specially trained law clerks.[303]

Although these procedures are a topic of discussion among both legal scholars[304] and scientific experts calling for reform of the courts,[305] they have

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not exist, a valid animal study can be used by the expert to support her opinion. *Id.*

300 Foster & Hube, *supra* n. 19, at 132 (noting that a negative studies raise questions such as whether there actually was no effect or whether the result is due to a deficiency in, or the sensitivity of, the study).

301 *Id.* (arguing that negative studies do not prove that there are no positive effects).

302 *General Electric Co. v. Joiner*, 522 U.S. 136, 148 (1997) (Breyer, J., concurring).

303 *Id.* at 149.

304 *See e.g.* Joe S. Cecil & Thomas E. Willging, *The Use of Court-Appointed Experts in Federal Courts*, 78 Judicature 41 (1994) (discussing the reasons why few judges utilize Federal Rule of Evidence 706 when authorizing the appointment of experts).

305 Angell, *supra* n. 18, at 205 (arguing that "the most important reform we could make

been frequently ignored by the federal courts.[306]

A. *Recent Interdisciplinary Programs Designed to Enhance the Use of Science in the Courts*

Recently, an increased awareness of the importance of scientific comprehension in the courts has led to more organized efforts by the federal judiciary to search for methods to improve the quality of the science used by the courts. One such development is the Federal Judicial Center collaboration with the National Academy of Sciences to develop a program within the Academy on "Science, Technology and Law."[307] Another national program that may provoke positive developments and better interdisciplinary communication involves the National Conference of Lawyers and Scientists, a joint committee of the American Association for the Advancement of Science and the Science and Technology Section of the American Bar Association. The National Conference of Lawyers and Scientists is currently developing a project to test the effect of an increased use of court-appointed, neutral, scientific or technical experts.[308] They propose that courts should appoint candidates recruited from scientific and professional organizations to serve as experts to resolve issues in cases where it is thought that the traditional adversarial system probably will not adequately provide the information needed for a reasoned and principled decision.[309]

B. *Individual Judges Can Enhance the Use of Science in Their Own Courtrooms*

In addition to these large-scale programs, some creative judges have been

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to raise scientific standards in the courtroom would be for judges to appoint expert witnesses").

[306] *See* Cecil & Willging, *supra* n. 304, at 46 (concluding that many judges believe that the use of court-appointed experts impedes the adversary system). "[T]he primary impediment to the use of experts . . . [is the] [j]udges' devotion to the adversarial presentation of evidence [which] causes them to reserve this procedure for those rare cases in which the adversarial system fails to provide information necessary for a reasoned and principled decision." *Id.*; Samuel R. Gross, *Expert Evidence*, 1991 Wis. L. Rev. 1113, 1191 (1991) (discussing studies that show that judges rarely use court-appointed experts).

[307] *Reference Manual on Scientific Evidence*, *supra* n. 3, at 5 (describing the objective of the project). Justice Breyer described this development in the following manner:

> This program will bring together on a regular basis knowledgeable scientists, engineers, judges, attorneys, and corporate and government officials to explore areas of interaction and improve communication among the science, engineering, and legal communities. This program is intended to provide a neutral, nonadversarial forum for promoting understanding, encouraging imaginative approaches to problem solving, and conducting studies.

Id.

[308] *Id.* at 7.

[309] *Id.*

experimenting with neutral scientific or technical experts. As Justice Breyer noted:

> Federal trial judges, looking for ways to perform this [inquiry into the admissibility of scientific evidence] function better, increasingly have used . . . pretrial conferences to narrow the scientific issues in dispute, pretrial hearings where potential experts are subject to examination by the court, and the appointment of specially trained law clerks or scientific special masters.[310]

One source of judicial creativity is Federal Rule of Evidence 706, which permits the court on its own motion, or on the motion of any party, to appoint neutral expert witnesses.[311] Some innovative judges have used this rule to appoint independent scientific or technical experts, not only as testifying witnesses but also as scientific special masters.[312] Rule 706 embodies the belief that "[l]ess tainted by partisanship, court appointed experts may identify areas where little disagreement in the scientific community exists, thereby narrowing the range of controversy."[313] Cross-examination of such experts therefore shifts its focus away from witness competence and integrity and towards areas where scientific evidence is in genuine dispute.[314] Recently, one district court judge hearing a case on silicone breast implants appointed a "neutral science panel" of four prominent and neutral scientists to prepare testimony for the court on the scientific basis of plaintiff's medical claims.[315]

Proposals involving neutral scientific experts sometimes arise from a concern that expert witnesses often have interests that are too closely aligned with the parties that are paying their (sometimes exorbitant) fees. In fact, the Advisory Committee Notes to Rule 706 begin by stating that "[t]he practice of shopping for experts, the venality of some experts, and the reluctance of many

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310 Breyer, *supra* n. 3, at 6.

311 Fed. R. Evid. 706 (2000) (granting courts the power to appoint expert witnesses on their own motion or on that of any other party). *See also* Joe S. Cecil &Thomas E. Willging, *Accepting Daubert's Invitation: Defining a Role for Court-Appointed Experts in Assessing Scientific Validity*, 43 Emory L.J. 995, 1002 (1994) (asserting that the application of Federal Rule of Evidence 706 derives from the court's inherent authority to invite experts to assist them).

312 Cecil & Willging, *supra* n. 304, at 1000-02 (discussing the range of functions expert witnesses have fulfilled in certain cases); *see also*, Jack B. Weinstein, *Individual Justice in Mass Tort Litigation: The Effect of Class Actions, Consolidations, and Other Multiparty Devices* 116 (Northwestern U. Press 1995) (contending that judges should appoint independent experts and encourage analysis by independent national groups in complexes cases).

313 Sanders, *supra* n. 21, at 378.

314 *Id.*

315 Olivia Judson, *Slide-Rule Justice*, 1999 Natl. J. 2882, 2885-86 (Oct 9,1999) (evaluating the impact of an Alabama federal district court's appointment of a panel of scientists to analyze data and decide whether breast implants cause chronic disease).

reputable experts to involve themselves in litigation, have been matters of deep concern."[316] Similar concerns have been echoed by legal commentators.[317] As Dr. Marcia Angell describes the problem,

> expert witnesses are selected by the contesting lawyers, paid by them, and their testimony is rehearsed in advance—circumstances unlikely to ensure competence, let alone objectivity. In fact, the whole point is precisely to find a 'qualified witness' who will be scientifically committed to your side.[318]

Thus, proposals for neutral experts also address concerns about slanted or biased scientific evidence provided by experts with a pecuniary interest in the outcome of the case. Other proposals derive from the assumption that our jury system provides little assistance to judges, lawyers, and jurors struggling to understand scientific evidence.[319]

Programs to enhance the comprehension of science in the courts should examine experiments like recent efforts undertaken in Arizona to enhance juror understanding and participation.[320] For the past five years, Arizona has enacted sweeping changes in state courtroom procedures allowing jurors to take notes,[321] ask questions, and, in civil cases, to discuss the trial prior to

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[316] Fed. R. Evid. 706 (2000) (advisory committee notes).

[317] *See* Michael S. Jacobs, *Testing the Assumptions Underlying the Debate about Scientific Evidence: A Closer Look at "Juror Incompetence" and Scientific "Objectivity,"* 25 Conn. L. Rev. 1083, 1092 (1993). Jacobs notes that

> [f]or the commentators, however, the problem with the expert witness industry has to do not with the quantity but with the quality of its product. Instead of offering us truthsayers, they claim the new firms sell us con artists; instead of steak we get sizzle. And, more to the point, the sizzle hopelessly confuses us. Competent lawyers cannot help us see through it, and ultimately we are deceived into verdicts that are palpably 'wrong.'

[318] Angell, *supra* n. 18, at 118 (insinuating that the role of the scientist and expert witness are at odds because an expert witness is supposed to give an opinion on, rather than a competent interpretation of, the data).

[319] *See* Robert D. Myers, Ronald S. Reinstein & Gordon M. Griller, *Complex Scientific Evidence and the Jury*, 83 Judicature 150, 152 (1999) (arguing that the current judicial system should be reformed to educate the jury better).

> What the research shows then, along with the experiments and experiences of active and concerned judges in complex cases, is that the trial process itself may be as much an impediment to jury comprehension and understanding as the complexity of the legal concepts and evidence, or the competencies of jurors.

Id. (citation omitted).

[320] *Id.* at 152-56 (describing Arizona's 1995 jury rule changes); *see also* Fred Misko Jr. & Frank E. Goodrich, *Managing Complex Litigation: Class Actions and Mass Torts*, 48 Baylor L. Rev. 1001, 1074-75 (1996) (discussing the procedure that might be employed in complex cases to increase juror comprehension).

[321] While allowing juror note-taking is within the discretion of the court, few jurisdictions allow the practice. Myers, Reinstein & Griller, *supra* n. 319, at 154 (arguing that courts should allow note-taking).

deliberations.[322] Arizona has also endeavored to enhance comprehension by rewriting and clarifying jury instructions.[323]

CONCLUSION

We live in a world infused with science and technology. Scientific discoveries and technical developments influence and alter our daily lives. As we grow more dependent on science, we will find that practitioners of science and law may not share the same visions or goals. When the goals of science and law collide, these disputes must be resolved using the facts of science and the methodologies of law. The awkward marriage of science and law in the courts has too often led to frustrated lawyers, overburdened judges, and abstruse scholarship.

To improve our ability to understand and use science within the federal courts we must treat the disjuncture between science and law not as a theoretical problem but as a practical one. First, we must comprehend the new legal methodology. Although *Daubert* may have created a vague and unwieldy standard, Justice Breyer's *Kumho* opinion crafted a better analytic tool. The Sixth and Seventh Circuits are likely just the first of the federal courts to recognize the significant impact of *Kumho* on the scope and nature of the judicial inquiry. Second, we must expand and enhance our understanding of basic scientific language, methods, and statistical measurements. This knowledge will improve our legal decision-making and enhance our ability to craft to craft creative interdisciplinary solutions for resolving legal cases that turn on highly complex scientific or technical information.

If legal practitioners and scholars maintain a broad focus on the range of scientific mistakes and misunderstandings that permeate the law, they can avoid being sidetracked by concerns limited to junk science. This broad view must also be objective. Those trained as advocates must recognize that scientific validity is independent of our legal goals. Justice Breyer has charged the courts to "aim for decisions that, roughly speaking, approximately reflect the scientific state of the art."[324] Although many of us may have chosen law school only after seeing our freshman chemistry grades, we are nevertheless up to this task.

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[322] *See id* (describing Arizona's 1995 reforms).

[323] *See id.* (explaining how jurors in Arizona receive pretrial instructions that define relevant legal terms and the elements of the alleged crime).

[324] Breyer, *supra* n. 11.