NO. 08-559

IN THE SUPREME COURT OF THE UNITED STATES

E.K. MCDANIEL, WARDEN, ET AL.
Petitioners,

v.

TROY BROWN
Respondent.

ON WRIT OF CERTIORARI
TO THE UNITED STATES COURT OF APPEALS
FOR THE NINTH CIRCUIT

BRIEF OF 20 SCHOLARS OF FORENSIC EVIDENCE AS *AMICI CURIAE* SUPPORTING RESPONDENTS

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TABLE OF CONTENTS

TABLE OF AUTHORITIES

CASES

RULES

REPORTS

BOOKS AND ARTICLES

INTEREST OF *AMICI CURIAE*

Amici Curiae are scholars who have published articles and books about the interpretation of forensic science evidence and about the appropriate way for experts to characterize such evidence when testifying in court.[1] Their goal is to provide information about the underlying scientific and statistical issues—information that will assist the Court in understanding the deficiencies in the scientific evidence in this case.

In this case, the District Court and Court of Appeals found that a key government witness made two critical errors when presenting DNA evidence to the jury. One of the errors arose from a mistake of logic known as "the prosecutor's fallacy." The other error concerned the likelihood of a DNA match between brothers.

Amici Curiae take no position on the procedural issues presented by this case, such as the standard of review for sufficiency of evidence claims or the rules for supplementing the record. However, they believe strongly that convictions obtained on the basis of materially false and misleading scientific testimony, such as the expert testimony presented in this case, should not be allowed to stand.

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[1] Pursuant to Rule 37.6, *Amici Curiae* state that no counsel for a party authored this brief in whole or in part, and no counsel or party made a monetary contribution intended to fund the preparation or submission of this brief. No person or entity other than *Amici Curiae* has made a monetary contribution to the preparation or submission of this brief. Counsel for the parties have consented to the filing of this brief.

SUMMARY OF FACTS AND CASE

In September 1994, respondent Troy Brown was convicted of sexual assault on a child. The dispositive evidence against him was a DNA test, conducted by Renee Romero of the Forensic Science Division of the Washoe County Sheriff's Office. Ms. Romero has a bachelor's degree in chemistry and a master's degree in cell biology, and had worked at the laboratory for over five years at the time of her testimony. (JA 412-13). She was a member of the Federal Bureau of Investigation's technical working group on DNA analysis methods, which creates DNA testing standards, and a provisional member of the American Academy of Forensic Sciences. (JA 413).

Ms. Romero testified that she tested both the crime-scene evidence and a known sample from Troy Brown using a DNA testing technique known as Restriction Fragment Length Polymorphism (RFLP) analysis. (JA 427).[2] Examining five loci, or places on the genomic strand, Ms. Romero concluded that Troy possessed a set of genetic characteristics that were also found in a semen stain on the victim's underwear. (JA 435-36).

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[2] For descriptions of RFLP analysis, *see generally* Norah Rudin & Keith Inman, *An Introduction to Forensic DNA Analysis* (2d ed. 2001); David H. Kaye & George F. Sensabaugh, Jr., Federal Judicial Center, *Reference Guide on DNA Evidence, in Reference Manual on Scientific Evidence* 485 (2d ed. 2000), http://www.fjc.gov/public/pdf.nsf/lookup/sciman00.pdf/$file/sciman00.pdf [hereinafter FJC Manual].

Ms. Romero was then asked to explain the strength of that match to the jury. Using what she repeatedly described as a "conservative" method, she reported that the likelihood that this particular genetic profile would be found in the population is roughly "one in 3 million." (JA 437).

The prosecutor then engaged in a series of exchanges, including a visual demonstration, intended to present this "one in 3 million" statistic in various—and he reiterated, equivalent—ways. The prosecutor invited Romero to present "another way to show that statistic" asking specifically "what is the likelihood that the DNA found in the panties [was from the defendant]" and "what would that percentage be?" (JA 458). Ms. Romero responded: "It would be 99.99[9]967 percent." (JA 458).[3] The prosecutor then asked the expert to write that percentage on a board and to subtract it from 100 percent. The display, which became Exhibit G, shows the numbers as follows:

```
100.000000
-99.999967
    .000033
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The prosecutor then asked whether it would be "fair to say" that "the likelihood that it is not Troy Brown would be .000033?" and that "just another way of looking at it" would be to say that "the chances that

[3] The transcript records Ms. Romero as saying 99.99967, but the exhibits and subsequent testimony suggest she actually said 99.999967. (JA 458).

the likelihood that …it's not the same… would be .000033?" (JA 460-461). The expert agreed that the two expressions were equivalent, adding "[t]hat's the way the math comes out." (JA 462). Underscoring the point, the judge said: "Let's make sure. It's the same thing—it's the same math just expressed differently. Is that correct?" The witness responded: "Yes. Exactly, your Honor." (JA 462).

During cross-examination, the defense lawyer asked Ms. Romero about the probability of a DNA match between brothers. This was a relevant inquiry because Mr. Brown is one of five brothers, and two of his brothers also lived in Carlin, Nevada. (JA 1543). Two others "were within the region, residing in Loa, Utah." *Brown v. Farwell,* 3:03-cv-00712-PMP-VPC, 2006 U.S. Dist. LEXIS 98154, at *12 (D.N.V. December 14, 2006). None of the brothers were tested to determine whether they share the genetic characteristics that incriminated respondent, even though some evidence pointed in their direction. Both brothers who lived in Carlin had also been out that night with Troy, and only one had an alibi, provided by his wife. (JA 103-104, 278). Moreover, the nine-year-old victim told police at least twice that her attacker was Trent Brown, the brother whose wife gave an alibi, and she did not identify Troy as her assailant in a photo line-up, although he lived ten trailers away and had been to her home repeatedly. (JA 522-523, 533-534).

Ms. Romero testified that the chance that one of respondent's brothers would share the matching genetic characteristics was 1 in 6500. (JA 469). She

testified that she had used a formula recommended by the National Research Council to compute that number.[4] The prosecutor then asked Ms. Romero to add to Exhibit G a figure that would apply to brothers. (JA 471-472). On the exhibit, Ms. Romero wrote:

100.00
<u>99.982</u>
.02

The prosecutor asked whether it would be "fair, then, to say that the likelihood of the parents having one child, and then the very next child having the same genetic code would be .02 percent?" and Ms. Romero said "yes."[5] (JA 472). The defense lawyer

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[4] Ms. Romero testified as follows:

> In the National Research Council report, the one I spoke about earlier, the committee wrote the report under the auspices of the National Academy of Sciences, they addressed that problem.…And they have a formula in there that they use…And in this case that turns out to be one in 6500. Meaning those two adults would have to mate and produce offspring 6500 times to come up with that pattern again.

(JA 469). It is clear from context that Ms. Romero was referring to a formula that appears on page 87 of the National Research Council's 1992 report. Committee on DNA Technology in Forensic Science, National Research Council, *DNA Technology in Forensic Science* 87 (1992) [hereinafter NRC 1992]. As explained below, however, she applied this formula incorrectly and, as a result, greatly understated the probability of a fraternal match.

[5] If the chances of a match were 1 in 6500, then the probability of a match would be .015 percent, rather than .02 percent. This

then asked whether the numbers would change if there were two brothers. Ms. Romero said no. (JA 472).

During his closing argument, the prosecutor argued that the DNA evidence was sufficient *by itself* to prove defendant's guilt. Recognizing the difficulty for laypersons in interpreting scientific evidence, he said that "[e]very day thousands of people get on a jet airplane and fly all over the world," even though "probably the vast majority of those people don't understand what makes a jet engine work or the mechanics or the engineering of it." (JA 723). However, "they still get on that plane and they fly," the prosecutor continued, "because it is reliable" and "it is provable."

The prosecutor closed by telling the jury that the DNA evidence proved there was a 99.999967 percent chance that Mr. Brown committed the crime:

> Now, the DNA. When you use the DNA, by itself, it's sufficient to prove beyond a shadow of a doubt that he committed this crime…
>
> …sometimes people use the phrase, I'm 99 percent sure about that. Well, in this case the evidence shows—how sure can you be? 99.999967 percent sure. (JA 730).

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appears to have either been a small computational error of no significance or an instance of rounding off.

Respondent was convicted and the Nevada Supreme Court upheld his conviction. During subsequent federal habeas proceedings, the District Court allowed respondent to supplement the record with a report prepared by Dr. Laurence D. Mueller, Professor of Ecology and Evolutionary Biology at the University of California, Irvine (hereafter "Mueller Report").

The Mueller Report identified material statistical errors in the trial testimony and argument. Specifically, the report highlighted that Ms. Romero: (a) conflated the probability that a person picked at random would have a particular profile with the probability that someone other than respondent was the actual source of the stain, an error known as "the prosecutor's fallacy"; (b) misrepresented the probability that siblings would share a genetic profile; and (c) greatly understated the likelihood that one of respondent's brothers might share his DNA profile, reporting it to be 1 in 6500.[6]

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[6] According to Professor Mueller, were Troy to have only one brother, the probability that this *single brother* would share the genetic characteristics that linked Mr. Brown to the crime was 1 in 263. Professor Mueller based this determination on the FBI's Caucasian database and a formula published in the National Research Council's 1996 report. Committee on DNA Forensic Science: An Update, National Research Council, *The Evaluation of Forensic DNA Evidence* (1996) [hereinafter NRC 1996]. Given that Troy had four brothers, Mueller also estimated the probability of finding a match among multiple brothers. Using standard probability theory, Mueller calculated the chance that among *two brothers* one or both would match those characteristics as 1 in 132, and the chance that among *four brothers* one or more would match as 1 in 66.

Based on the Mueller report, the District Court and Court of Appeals found that Ms. Romero's testimony had been "inaccurate and misleading." *Brown v. Farwell*, 525 F.3d 787, 789 (9th Cir. 2008). Noting that the petitioners had "conceded at least twice that, absent this faulty DNA testimony there was not sufficient evidence to sustain Troy's conviction," the Court of Appeals sustained the District Court's conclusion that Mr. Brown was denied due process and affirmed the District Court's grant of the petition of habeas corpus. *Id.* at 787.

SUMMARY OF ARGUMENT OF *AMICI CURIAE*

In presenting the DNA evidence to the jury, the government's expert witness, Ms. Romero, made two critical errors: she wrongly presented the *random match probability* as a *source probability*, and she radically underestimated the probability of a sibling match among the brothers.

First, Ms. Romero equated a *random match probability* with a *source probability*. The *random match probability* is the probability that a randomly chosen person unrelated to respondent would, like respondent, match the DNA profile found in the

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By analogy, imagine rolling a pair of dice. The probability that any one roll will produce "snake eyes" is only 1 in 36, but the probability of snake eyes becomes more likely the more times one rolls. The difference between the formula (mis)used by Ms. Romero and the formula used (correctly) by Professor Mueller will be elaborated below.

semen stain. Ms. Romero estimated the chances of such a random match to be 1 in 3 million and that estimate is not contested. Based on that estimate, however, she went on to testify about the *source probability—i.e.*, the probability that respondent was the source of the semen. She told the jury, in essence, that there is only one chance in 3 million that the semen came from *someone other than respondent* and therefore only one chance in 3 million that respondent was *not* the source of the semen. As this brief will explain, her testimony about *source probability* was fallacious, scientifically groundless and misleading. It rested on a logical error that is widely recognized in both the scientific and legal literature, where it has been called the "prosecutor's fallacy," the "source probability error," and the "transposition fallacy" (as we will explain below).

Ms. Romero's second error was to vastly underestimate the probability that one of respondent's four brothers would match the profile of the stain. She told the jury that the probability of a fraternal match was 1 in 6500, but this number is wrong. When computed correctly, by a method well known to geneticists and forensic scientists, the probability that any one of the brothers considered singly would match is 1 in 263; with four brothers, the probability that at least one would match is 1 in 66. The prosecutor repeated and reinforced Ms. Romero's errors in his closing statement to the jury. Moreover, he made matters worse by using Ms. Romero's incorrect testimony to effectively usurp the jury's role, erroneously telling them that the DNA

evidence *by itself* had proven respondent's guilt beyond a reasonable doubt.

The inaccurate testimony and misleading arguments compromised the fairness of respondent's trial. *Amici Curiae* call upon this Court to remedy this unfairness and to set standards that will preclude future such errors. Forensic science has tremendous potential to contribute to the cause of justice, but that potential will be undermined if courts allow scientific evidence to be distorted and misused as it was in this case. Setting and enforcing attainable standards will help ensure that forensic science evidence in general, and DNA evidence in particular, will achieve its potential and merit its good reputation in the criminal justice system.

ARGUMENT

I. THE GOVERNMENT WRONGFULLY USURPED THE ROLE OF THE JURY WHEN IT USED INACCURATE TESTIMONY TO ARGUE THAT THE DNA EVIDENCE PROVED RESPONDENT'S GUILT.

When DNA evidence is used in a criminal trial to identify the defendant as a possible source of a biological sample, such as a semen stain, the jury must assess the *source probability—i.e.*, the probability that defendant was the source of the stain. But DNA evidence cannot, by itself, establish the *source probability*. It can show only that the defendant possesses a set of genetic characteristics

that were also found in the stain, and then provide information about the rarity of those characteristics. Unless the characteristics are unique, however, the DNA test cannot establish that defendant *was* the source. It can, at best, establish that he is one of a group of people who *could have been* the source, and provide data useful for estimating the size of that group.

To help jurors assess the strength of DNA evidence, experts typically offer statistics on the frequency (or rarity) of the matching DNA characteristics in various reference populations. The expert might say, as in this case, that one person in 3 million would have the matching characteristics. These statistics are often called *random match probabilities* because they reflect the probability that a randomly chosen person would have the matching characteristics.

It is easy to become confused and assume that the *random match probabilities* provided by DNA experts are equivalent to *source probabilities*. When the random match probability is one in 100, for example, people sometimes reason that if there is only a one in 100 (1 percent) chance that the defendant would match if he was *not* the source then there must be a 99 percent chance that he *is* the source. Alternatively, people sometimes think that the random match probability reflects the probability that *someone other than the defendant* would match; they then reason that if there is only a one percent chance someone else is the source then there must be a 99 percent chance defendant is the

source. Both lines of reasoning are indisputably wrong. Yet conflating *random match* and *source probability* in this way is an error so common it has come to be known as the "prosecutor's fallacy,"[7]

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[7] The term "prosecutor's fallacy" was originated by William Thompson (one of the authors of this brief) and Edward Schumann in 1987. *See* William C. Thompson & Edward L. Schumann, *Interpretation of Statistical Evidence in Criminal Trials: The Prosecutor's Fallacy and the Defense Attorney's Fallacy*, 11 Law & Hum. Behav. 167 (1987). This term has been widely used in the scholarly literature, *see, e.g.*, Dawn McQuiston-Surrett & Michael J. Saks, *Communicating Opinion Evidence in the Forensic Identification Sciences: Accuracy and Impact*, 59 Hastings L.J. 1159, 1178-79 (2008); Robert Aronson & Jacqueline McMurtrie, *The Use and Misuse of High-Tech Evidence by Prosecutors: Ethical and Evidentiary Issues*, 76 Fordham L. Rev. 1453, 1478-79 (2007); Boaz Sangero & Mordechai Halpert, *Why A Conviction Should Not Be Based on a Single Piece of Evidence: A Proposal for Reform*, 48 Jurimetrics J. 43, 44 (2007); David J. Balding, *Weight-of-Evidence for Forensic DNA Profiles* (2005); Bernard Robertson and G.A. Vignaux, *Interpreting Evidence: Evaluating Forensic Science in the Courtroom* (1995); David J. Balding & Peter Donnelly, *The Prosecutor's Fallacy and DNA Evidence*, 1994 Crim. L. Rev. 711; William C. Thompson, *Are Jurors Competent to Evaluate Statistical Evidence?*, 52 Law & Contemp. Probs. 9 (1989). The prosecutor's fallacy has been discussed both directly and indirectly in court opinions in the United States, *see, e.g.*, *United States v. Morrow*, 374 F.Supp.2d 51, 66 (D.D.C. 2005); *United States v. Shea*, 957 F.Supp. 331, 345 (D.N.H. 1997); *United States v. Chischilly*, 30 F.3d 1144, 1156-57 (9th Cir. 1994); *State v. Spann*, 617 A.2d 247, 258 (N.J. 1993); *State v. Bible*, 858 P.2d 1152, 1185 n.18 (Ariz. 1993); *State v. Bloom*, 516 N.W.2d 159, 163 (Minn. 1994), as well as abroad in the United Kingdom, *see*, *e.g.*, *R. v. Gray*, [2005] EWCA 3564 (Eng. C.A.); *R. v. Dallagher*, [2002] EWCA Crim. 1903 (Eng. C.A.); *R. v. Doheny,* [1997] 1 Cr. App. R. 369, 372-73 (Eng. C.A. 1996), and Australia, *see, e.g.*, *R. v. Keir,* [2002] NSWCCA 30, 127 A.

although some scholars prefer the terms "transposition fallacy"[8] or "ultimate issue error."[9] By whatever name, this mistake has been roundly condemned, including by the Federal Judicial Manual,[10] the 1996 National Research Council

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Crim. R. 198; *R. v. GK*, [2001] NSWCCA 413, 125 A. Crim. R. 315; *R. v. JCG*, [2001] NSWCCA 504, 127 A. Crim. R. 493.

[8] Some experts prefer to call this error the "fallacy of the transposed conditional," because it arises from transposing two conditional probabilities. The random match probability represents the conditional probability of a match *if* the person being tested is not the source; the source probability is the conditional probability that a person is the source *if* the person matches. *See, e.g.*, Ian W. Evett & Bruce S. Weir, *Interpreting DNA Evidence: Statistical Genetics for Forensic Scientists* 30-32, 227 (1998); Richard Lempert, *Some Caveats Concerning DNA as Criminal Identification Evidence: With Thanks to the Reverend Bayes*, 13 Cardozo L. Rev. 303, 306 (1991); Ian W. Evett, *Avoiding the Transposed Conditional*, 35 Sci. & Just. 127 (1995); *Forensic DNA Evidence Interpretation* 50-52 (John S. Buckleton, Christopher M. Triggs & Simon J. Walsh, eds., 2004); David P. Leonard, et al., *The New Wigmore: A Treatise on Evidence* (1998).

[9] Jonathan Koehler, *Error and Exaggeration in the Presentation of DNA Evidence at Trial*, 34 Jurimetrics J. 21, 27, 32 (1993). Professor Koehler uses the term "source probability error" to describe the conflation of the random match probability with source probability, and uses the term "prosecutor's fallacy" or "ultimate issue error" to describe the conflation of random match probability with the probability of guilt or innocence. Applying that taxonomy here, Ms. Romero committed the source probability error, while the prosecutor committed the prosecutor's fallacy.

[10] FJC Manual, *supra* note 2, at 539.

report on DNA,[11] and by courts in the United States and abroad.[12]

The underlying error can be demonstrated with a simple illustration. Imagine that a blood stain from a crime scene undergoes DNA testing, which reveals that it contains the gene for colorblindness. Suppose further that the defendant's DNA also has this trait, and that population studies have found that only one person in 100 in the United States has the colorblindness gene. What can we conclude from the DNA evidence about the *source probability—i.e.*, the probability that defendant is the source of the blood?

People are often surprised to realize that we can draw no meaningful conclusions about the *source probability* from the DNA evidence alone. The DNA evidence shows that the defendant falls within a small fraction of the human population (1%) consisting of people who could have been the source. But one percent of the population includes a very large number of people; the DNA evidence does not reveal which of those many people *is* the source of the blood, nor does it tell us whether any particular member of that group, such as the defendant, is any more or less likely than any other member to be the source. Hence, it cannot prove, *by itself*, that there is

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[11] NRC 1996, *supra* note 6, at 133.

[12] *See supra* note 7; *see also* Nuffield Council on Bioethics, *The Forensic Use of BioInformation: Ethical Issues* 68-72 (2007) (condemning the prosecutor's fallacy), *available at* http://www.nuffieldbioethics.org/go/ourwork/bioinformationuse/publication_441.html.

a 99 percent chance that the defendant was the source.[13]

Drawing useful conclusions about *source probability* thus generally requires considering DNA evidence in conjunction with other evidence in a case. If other evidence points strongly to defendant's guilt, a jury could reasonably conclude that there is a high likelihood that defendant is the source of the blood, even though he is only one of many people who could have been the source. In contrast, if the other evidence points to someone else, a jury could reasonably conclude that the match to defendant was just a coincidence. As any player of poker knows, seemingly improbable events sometimes occur just by chance.[14]

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[13] Members of the matching group cannot all have a 99 percent chance of being the source. Because only one can be the actual source, the probabilities that each is the source must necessarily sum to one.

[14] Another analogy may help clarify this point. Suppose you join a poker game and in the first hand one player deals herself a royal flush. This is an extremely unlikely event if the player is dealing fairly. The probability of dealing oneself a royal flush, in a random deal of cards, is only 0.000154%, or approximately one chance in 650,000. Does it therefore follow that the player is unlikely to have been dealing fairly—*i.e.*, that she is probably cheating?

A person who adopted the fallacious logic underlying Ms. Romero's testimony in this case would conclude that because there is only 1 chance in 650,000 of receiving a royal flush in a fair deal, there must therefore be only one chance in 650,000 that the player was dealing fairly, and hence a 99.999846 percent chance that she was cheating. But this conclusion would be foolish, because the low probability of getting a royal flush is but one of many facts that must be considered to assess

In light of this analysis, it should now be clear that, in a case of this type, an expert witness cannot draw conclusions about *source probability* from DNA evidence alone. If an expert expresses an opinion about *source probability*, the expert is either making a fallacious statement based on a misunderstanding of probability, or the expert is basing the opinion on information other than the scientific findings, such as an assessment of the strength of the non-scientific evidence in the case. In the former situation, the opinion about source probability is unreliable and invalid; in the latter situation, the opinion goes beyond the scope of the expert's legitimate testimony by relying upon the expert's judgment of evidence outside her scientific expertise. We contend that it is fundamentally inconsistent with both good scientific practice and with the courts' interest in providing juries with accurate and helpful expert evidence for experts to offer their own opinions about source probability.[15]

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the probability of cheating. If the dealer is a person that you believe to be of sterling character, such as a clergymember or judge, it would be quite reasonable to conclude that she just got lucky rather than cheated, notwithstanding the long odds against dealing a royal flush. If, on the other hand, the dealer is a notorious card shark, you might reasonably conclude the probability of cheating was much higher. To draw conclusions about the probability of cheating you would need to consider all the circumstances—it would be fallacious to equate the probability she was dealing fairly with the probability of dealing a royal flush.

[15] The only possible exception would be instances in which the expert determines, based solely on the scientific evidence, that two items share one-of-a-kind or unique features. In such cases, experts at times conclude with certainty that the two

matching items have a common source, which is tantamount to opining that the random match probability is effectively zero. *See* Keith Inman & Norah Rudin, *Principles and Practices of Criminalistics*: *The Profession of Forensic Science* (2001); William C. Thompson & Simon A. Cole, *Psychological Aspects of Forensic Identification Evidence, in Expert Psychological Testimony for the Courts* 31, 44-46 (Mark Costanzo et al. eds., 2006). We distinguish such testimony, called "individualization testimony," from source probability testimony.

Serious questions have been raised about the scientific foundations for individualization testimony. For example, a recent report of the National Research Council declared that "[w]ith the exception of nuclear DNA analysis . . . no forensic method has been rigorously shown to have the capacity to consistently, and with a high degree of certainty, demonstrate a connection between evidence and a specific individual or source." National Research Council of the National Academies, *Strengthening Forensic Science in the United States: A Path Forward*, at S-5 (Prepublication Copy Feb. 2009) [hereinafter NRC 2009]; *see also* Simon A. Cole, *Where the Rubber Meets the Road: Thinking About Expert Evidence as Expert Testimony*, 52 Vill. L. Rev. 803, 835-36 (2007). With DNA analysis, experts generally declare that two samples have a common source only when the random match probabilities are so exceptionally low as to render it unlikely that the matching profile would be duplicated in the human population. *See* NRC 1996, *supra* note 6, at 194-202. Even those conclusions are controversial because they depend on an arbitrary decision about just how low the random match probability must be for the probability of finding another matching profile to be deemed effectively zero. *Id*. at 193-95; Thompson & Cole, *supra*, at 44-46. But that issue—whether individualization might be warranted when the random match probability is sufficiently minuscule—does not arise in this case and we offer no comment on it. Our contention here is that forensic scientists should express no opinion about source probability in cases such as this one, in which no one claimed or could have credibly claimed that the matching characteristics clearly were so rare as to be unique.

Ms. Romero's testimony in this case is a classic example of the source probability error. Upon determining that respondent had a DNA profile consistent with the profile found in the semen stain, Ms. Romero used an accepted method to determine the frequency with which that profile would occur in the general population—in other words, the *random match probability*. Ms. Romero estimated the frequency to be 1 in 3 million, or .000033 percent. That estimate is not being contested although, as discussed below, it reflects the probability of a random match among people *unrelated* to Mr. Brown; the probability of a match among his relatives, particularly close relatives like brothers, would be far higher.

The problem is that Ms. Romero then repeatedly misrepresented her calculation of the *random match probability* as a statement of the *source probability*. She wrongly testified that there was a 99.999967 percent chance that Troy Brown was the source of the semen. She correspondingly averred that there was only a .000033 percent chance that he was *not* the source. These conclusions about source probability are scientifically groundless. As discussed above, the DNA evidence by itself does not allow direct evaluation of *source probability*.[16]

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[16] Given that there are over 300 million people in the United States, it would be expected that roughly 100 people in the United States share this profile (and we focus here just on people unrelated to Mr. Brown, ignoring for the moment his relatives). The DNA evidence establishes that respondent falls within that group, but it does not distinguish him from anyone else who falls within that group. Hence, it does not establish

The prosecutor compounded this error by arguing in closing that the DNA evidence, by itself, proved defendant's guilt by 99.999967 percent certainty. The prosecutor's statement was wrong in two ways. Not only did it equate *random match probability* with *source probability*, it equated *source probability* with the probability of guilt.[17]

Some scholars have proposed that experts use a mathematical formula known as Bayes' theorem[18] to make estimates of *source probability* on the basis of forensic evidence.[19] In order to apply Bayes' theorem

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the likelihood that he, rather than another group member, was the source of the semen.

[17] For a discussion of the dangers of equating source probability with the probability of guilt, see Koehler, *supra* note 9, and Laurence Tribe, *Trial by Mathematics: Precision and Ritual in the Legal Process*, 84 Harv. L. Rev. 1329, 1361-68 (1971). Among other problems, it ignores the potential weakness of the inferential connection between proof of source and proof of guilt.

[18] Thomas Bayes, *An Essay Towards Solving a Problem in the Doctrine of Chances*, 53 Phil. Transactions of the Royal Society of London 370-418 (1763). For discussions about the application of Bayes' theorem in a legal context, see Tribe, *supra* note 17; Richard Lempert, *Modeling Relevance*, 75 Mich. L. Rev. 1021 (1976-77).

[19] These proposals have been controversial. *Compare*, *e.g.*, Michael O. Finkelstein & William B. Fairley, *A Bayesian Approach to Identification Evidence*, 83 Harv. L. Rev. 489 (1970) (proposing use of Bayes' theorem), *with* Tribe, *supra* note 17 (elaborately critiquing such proposals). This controversy has extended to the DNA context. *Compare, e.g.*, Kaye & Sensabaugh, *supra* note 2, at 536-37, 544-45 (discussing applicability of Bayes' theorem to DNA evidence);

in this manner, however, the expert must estimate a *prior probability*, which here is an estimate of the probability that respondent was the source of the stain based on all evidence *other than* the DNA evidence. The theorem then specifies how estimates of *prior probability* and *random match probability* can be combined to generate an estimate of *source probability*.

There is no evidence that Ms. Romero used Bayes' theorem to generate her source probability estimates in this case. It appears, instead, that she simply fell victim to the source probability error. Indeed, to have used Bayes' theorem would have been improper for two reasons. First, as previously explained, a Bayesian analysis requires quantification of a prior probability, yet Ms. Romero was neither in a position to assess the non-scientific evidence nor expressly charged with that task. Second, because her testimony made no mention of Bayes' theorem or prior probability, jurors would have been misled about the basis for her scientific conclusions. That is, the jurors would never have known that Ms. Romero's putatively scientific conclusions about

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and NRC 1996, *supra* note 6 (discussing a possible method of presenting source probabilities derived from Bayes' theorem to juries), *with* William C. Thompson, *Accepting Lower Standards: The National Research Council's Second Report on Forensic DNA Evidence*, 37 Jurimetrics J. 405, 422-23 (1997) (critiquing the NRC proposal). Although Bayesian calculations have been used in civil paternity cases, *see* D. H. Kaye, *The Probability of an Ultimate Issue: The Strange Cases of Paternity Testing,* 75 Iowa L. Rev 75 (1989), such calculations have been generally been rejected, for good reason, in criminal trials, *see e.g.*, *State v. Skipper*, 637 A.2d 1101, 1105-08 (Conn. 1994).

source probability depended in part on her own veiled consideration of the value of the non-scientific evidence. Hence, even if Ms. Romero used Bayes' theorem to reach her conclusions, her testimony about source probability remains improper and highly misleading.[20]

Amici Curiae take the position that forensic scientists should never be allowed to express opinions about *source probabilities* when those opinions rest on fallacious reasoning or depend in part on their own assessment of non-scientific evidence.[21] Such testimony is easily misleading.

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[20] Here we are discussing an expert's use of Bayes' theorem to generate her own estimates of source probability, which were then presented to the jury as scientific conclusions. That is the only application of Bayes' theorem that might possibly have occurred in this case, and if it occurred it was clearly improper. There are, of course, other ways that Bayes' theorem might be used in trials that could be less problematic. For example, there have been a number of proposals to have experts explain Bayes' theorem to jurors or to provide jurors with "decision-aids" that illustrate the way Bayes' theorem might be used to draw conclusions about *source probability* from jurors' own estimates of *prior probability*. *See supra* notes 18 and 19. Although fascinating, these proposals are not directly relevant to this case. In this case Ms. Romero did not offer the jury "decision aids" to help them integrate the scientific evidence with their own evaluations of the non-scientific evidence in order to assess the source probability; she presented what purported to be her own scientific conclusions regarding the source probability.

[21] In other words, experts should not be permitted to embed a hidden assumption about a *prior probability* into a conclusion about *source probability*. *Amici Curiae* take no position on whether experts should be allowed to present "decision aids" to

Jurors are unlikely to recognize fallacies in an expert's reasoning; nor are they likely to understand instances in which the expert's scientific conclusions are derived, in part, from the expert's assumptions about the strength of other evidence in a case. Indeed, part of the problem with *source probability* testimony is that it implies that scientific evidence can prove things that it cannot prove. It suggests that the scientific evidence is all that need be considered when, in fact, scientific evidence can only be appreciated properly when considered in conjunction with all the other evidence.

This case underscores the dangers of misleading source probability testimony. Where there is evidence pointing away from the defendant and towards another possible perpetrator, such as a brother, jurors might reasonably have doubts about the probability that the defendant was the source notwithstanding the DNA evidence—if they understand the DNA evidence properly. The problem with the source probability testimony presented in this case is that it ruled out any such doubts. The expert and the prosecutor told the jury that the DNA evidence, by itself, proved that defendant was over 99% likely to be the source of the semen, and to be guilty, creating a false aura of scientific certainty about a conclusion that could properly be assessed only in light of the evidence as a whole.

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instruct jurors on how to use Bayes' theorem to make their own assessments of source probability. *See supra* note 20.

Without question, the DNA evidence in this case has a great deal of probative value. Any rational juror would increase his or her estimate of the probability that Mr. Brown was the source upon learning that he shared the same DNA profile as the semen stain. But a juror's ultimate conclusion about the source probability in this case should have rested on an assessment of the case as a whole, and with an accurate understanding of the actual statistical probabilities. By erroneously telling the jury that the DNA evidence, *by itself*, proved there was a 99.999967 percent chance that Mr. Brown was the source, Ms. Romero and the prosecutor short-circuited full consideration of the determinative issue. They provided a groundless and inappropriate "scientific" answer to the central question in the trial—a question that should have been left for the jury to answer based on all of the evidence.

II. THE JURY WAS WRONGLY INFORMED THAT THE PROBABILITY OF A FRATERNAL MATCH WAS SIGNIFICANTLY LESS LIKELY THAN WAS ACTUALLY THE CASE.

In addition to conflating the random match and source probabilities, the scientific testimony in this case dramatically understated the probability that one of respondent's brothers might also have matched the evidence. Ms. Romero calculated the probability as 1 in 6500, when the correct calculation shows that the probability that any one of the brothers considered singly would match is 1 in 263; the probability that, among respondent's four

brothers, at least one of the four would match is 1 in 66. Thus, Ms. Romero's statements suggested it was up to 100 times less probable that there would be a fraternal match than in fact was the case.

The random match probability is an estimate of the likelihood that a randomly drawn person *unrelated to the defendant* will share the characteristics that link the defendant to the evidence. It is based on the rate of occurrence of the relevant genetic traits in the population at random. Because we inherit genetic characteristics from our parents, however, genetic variation is far more limited among siblings, which increases the likelihood of a match.[22]

Standard formulae exist for computing the probability of a match between siblings. However, Ms. Romero appears to have both used an inappropriate formula and used it incorrectly.

A. *The formula that the government's expert claimed to have used for computing the fraternal match probability was inappropriate.*

Ms. Romero told the jury that she based her calculation on a formula published by the National

[22] Specifically, each person has two pieces of genetic material, called "alleles," at each locus. They inherit one from each parent (*i.e.*, one of each parent's own two alleles). Thus, whereas the possible number of combinations among related people is limited to the alleles possessed by their parents, the combinations among unrelated people reflect the full range of possible alleles.

Research Council. From the context of her remarks, it is clear that she was referring to the 1992 NRC Report.[23] This report contains only one formula concerning the probability of a match between brothers.[24]

This formula is not appropriate for estimating the probability that another brother would have respondent's DNA type. The formula estimates the *average* probability that two brothers will have the same genetic types at a series of loci –without regard to the specific types in a particular case. The probability of a fraternal match in any particular case may be higher or lower depending on the genetic characteristics that the individual happens to have. Relying on the average in a particular case is analogous to using the average income of all lawyers to estimate the income of a particular lawyer. The average will overstate the income of some lawyers and understate the income of others.

B. ***The calculations that the expert made using the inappropriate formula were themselves incorrect.***

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[23] NRC 1992, *supra* note 4.

[24] The report uses the formula to illustrate the fact that, on average, the DNA of brothers is more similar than the DNA of randomly selected individuals. It does not suggest that the formula be used, as Ms. Romero did, to estimate the probability of a match in a specific case. *Id*. at 87. Formulas that are more suitable for the latter purpose are available in the NRC 1996 report that updated the previous edition.

Amici attempted to replicate Ms. Romero's computations of the fraternal match probability, using the formula Ms. Romero testified that she had used, and obtained a result significantly more favorable to respondent than the result that Ms. Romero presented to the jury. Ms. Romero testified that the probability a brother would match was 1 in 6500. However a correct application of the NRC formula yields a match probability exceeding 0.0045, or approximately 1 in 222.[25] Either Ms. Romero did

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[25] According to the NRC 1992 formula, the probability that two siblings will match at k genetic loci is approximately $(.25 + 0.5p + 2p^2)^k$ where p is the average chance that two alleles will match (also called the apparent homozygosity rate). The DNA test in this case examined five loci, so k would be 5. The homozygosity rates for those loci ranged from .07 to .21. *See* Bruce Budowle et al., *Fixed-bin analysis for statistical evaluation of continuous distributions of allelic data from VNTR loci, for use in forensic comparisons*, 48 Am. J. Hum. Genetics 841 (1991) (the relevant data appear in Table 8). Hence, the value of p should have been .10 or higher. Consequently, if Ms. Romero had applied this formula correctly, she should have computed the probability of a match between brothers to be at least $(.25 + 0.5(.10) + 2(.10)^2)^5 = 0.0045$, or approximately 1 in 222 rather than 1 in 6500. Her error is difficult to understand. The only variable she would have needed to look up was the "homozygosity rate," p, but even if she had mistakenly taken that rate to be zero, she should still have estimated the probability of a match between brothers to be $.25^5 = 0.00098$ or approximately 1 in 1024, which is considerably higher than 1 in 6500. All of these calculations are, of course, based on the inappropriate formula in the 1992 NRC report. As explained *infra*, the appropriate formula, from the 1996 NRC report, produces a fraternal match probability in this case of 1 in 263, as Professor Mueller correctly reported.

not use the formula she testified to or her computations were wrong.

C. *The misleading fraternal match testimony invited the repetition of the source probability error with regard to the fraternal match probability.*

Ms. Romero's gross misrepresentation of the fraternal statistical probabilities was exacerbated when, prompted by the prosecutor, she illustrated her inaccurate calculations before the jury. Using the earlier exhibit that wrongly depicted the *random match probability* as the *source probability*, Exhibit G, the prosecutor asked Ms. Romero to translate her calculations into percentages. (JA 471). Ms. Romero accordingly subtracted her estimates from 100, as she had done in the earlier illustration. The prosecutor then asked her whether it "would be fair, then to say that the likelihood of the parents having one child, and then the very next child having same genetic code would be .02 percent." (JA 472). Ms. Romero responded "yes." (JA 472).

This illustration -- no doubt persuasive and vivid, given the prosecutor's repeated desire to express the numbers to the jury visually and by "mak[ing] this into a percentage where I can understand it" -- compounded the prejudicial effect of Ms. Romero's various incorrect statements. (JA 461). Having been told earlier that the exhibit represented the probability that the defendant was the source of the semen stain rather than a random person (the *source probability*), the jurors might well have concluded

that this exercise depicted the probability that the defendant rather than one of his brothers was the source (a *fraternal source probability*, if you will). In other words, the display could well have led jurors to interpret the erroneous fraternal match probability in a manner consistent with the prosecutor's fallacy or source probability error.

Based on this presentation, jurors would have wrongly understood that the DNA evidence established that there was a 99.982 percent chance the semen stain came from Troy Brown and only a .02 percent chance it came from one of his brothers. But this impression is false because, as discussed above, the DNA evidence, *by itself*, cannot establish a *source probability*—it cannot establish the probability that respondent (rather than one of his brothers) was the source of the semen. Source probabilities can only be assessed in light of all the evidence. The rarity or commonness of genetic material in the population at large, or even among a particular pool of suspects, is only one factor that must be considered to assess source probability, even if it is clearly an important factor. In a case such as this one, where some of the evidence pointed away from respondent and toward one of his brothers, it was vitally important to have an accurate estimate of the probability of a fraternal match.

D. ***The government's expert wrongly implied that the source probability was unaffected by respondent's having multiple brothers.***

After presenting the figure of .02 percent in a manner that implied that it represented the probability that one of respondent's brothers was the source of the semen, the defense lawyer asked Ms. Romero whether that number "would change at all with two brothers?" She said "no." (JA 472). By giving this terse negative response, without elaborating or explaining, Ms. Romero undoubtedly left the jury with the false impression that her (incorrectly) low statistic of 1 in 6500 (or .02 percent) reflected the probability of that one of defendant's brothers was the source of the semen, regardless of the number of brothers.

The fact that respondent has four brothers does not affect the *conditional probability* of a match to any particular brother,[26] which remains one in 263,[27] but it does affect the probability that *at least one* of the brothers will have the matching profile. Hence, it is an important factor for jurors to consider when assessing the likelihood that someone other than respondent could be the source of the semen stain. Just as the chances of winning a raffle increase as one buys more tickets, so does the likelihood of

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[26] The term "conditional probability of a match" means the probability that the brother would match if he was *not* the source of the semen—in other words, the probability of a random match for a brother.

[27] As discussed below, the fraternal match probability in this case was actually 1 in 263. This number represents the conditional probability of finding a match to one of respondent's brothers *given that* the brother was *not* the source—it does not reflect the probability that the brother *was* the source.

finding a DNA match to a brother increase as one has more brothers.

E. *The correct calculation of the fraternal match probability paints a dramatically different statistical picture than the one presented to the jury.*

As the record reflects, Dr. Mueller computed the probability of a fraternal match using the formula found in the 1996 NRC report on DNA evidence.[28] This formula takes into account the specific genetic characteristics (alleles) of the person in question and is therefore appropriate for use in a forensic case. We have done our own independent computation of the fraternal match probability in this case, using the same formula, and using frequencies derived from the FBI's Caucasian database, and have obtained results that are virtually identical with those in the Mueller report.

By our computations, the probability of a fraternal match to the genetic profile of the respondent is 1 in 263.[29] The probability of finding this profile among

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[28] NRC 1996, *supra* note 6, at 113 (Formula 4.9).

[29] The table on the following page shows the DNA profile found in the semen stain, the frequency of the profile's various genetic characteristics (alleles) using the FBI's Caucasian database, and the probability of a fraternal match at each locus as computed by NRC 1996 formula 4.9, *supra* note 6. Discrepancies between our and Dr. Mueller's numbers are insignificant and probably due to the use of a different number of digits for purposes of rounding.

one or more of the four brothers can be computed based on elementary principles of probability.[30] There is one chance in 66 of finding it at least once among all four brothers and one chance in 131 of finding it in any two of them.

To the extent that other evidence created room for doubt about whether respondent or one of his brothers was the assailant, the precise value of the fraternal match probability constituted a critical component of a rational evaluation of respondent's guilt. The difference between the inaccurate number

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Locus	**Allele**	**Frequency**	**Frat. Match Prob.**
D2S44	3297	.089	.314
	1640	.141	
D4S139	14577	.124	.320
	10101	.124	
D10S28	4386	.065	.269
	653	.009	
D14S13	1846	.166	.361
	1517	.209	
D17S79	1757	.186	.391
	1525	.276	
Overall Probability			**.0038**
or... **1 in**			**263**

[30] The probability that at least one of several brothers will match is computed using the formula $1-(1-p)^n$, where p is the probability a single brother will match and n is the number of brothers.

that the prosecution's expert presented and the true probability could very well have made the difference between conviction and a reasonable doubt.

CONCLUSION

This case provides an unfortunate example of forensic science gone seriously awry and of the failure of the lawyers and the trial judge to recognize the errors. Ms. Romero's testimony about source probabilities was flawed and inappropriate. Her testimony about the probability of a fraternal match was flatly inaccurate. The prosecutor made matters worse by manipulating Ms. Romero's incorrect testimony into a fallacious argument that the DNA evidence, *by itself*, constituted proof beyond a reasonable doubt of respondent's guilt. By claiming that the scientific evidence proved something that it did not and could not prove, the government built an unfair and misleading case against respondent.

Convictions based on forensic science have become increasingly common.[31] Yet the criminal justice system has sometimes faltered in the task of

[31] NRC 2009, *supra* note 15. This Court has observed that "DNA testing has an unparalleled ability both to exonerate the wrongly convicted and to identify the guilty." *District Attys. Off. for the Third Jud. Dist. v. Osborne*, 129 S.Ct. 2308, 2312 (2009). At the same time, this Court has acknowledged both that "[s]erious deficiencies have been found in the forensic evidence used in criminal trials," and that forensic analysts "sometimes face pressure to sacrifice appropriate methodology for the sake of expediency," *Melendez-Diaz v. Massachusetts*, 129 S.Ct. 2527, 2537 (2009).

ensuring the reliability of such evidence.[32] Clearly the task is not an easy one. The erroneous testimony in this case did not come from a charlatan, but from a forensic scientist with respectable credentials. Ms. Romero had an advanced degree and at the time of her testimony served on a national advisory committee; she currently serves as the crime laboratory director of her county. The attorneys here undertook direct and cross-examination of the evidence, and even the judge on occasion intervened in an effort to clarify. All the normal accoutrements of the trial process were present here and it undoubtedly appeared, to most observers, that the system was functioning fairly. But this trial was not fair. The DNA evidence, on which the case turned, was presented in a manner that seriously misrepresented its meaning and value with respect to the central issue of the case—respondent's identity as the perpetrator.

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[32] *Melendez-Diaz*, 129 S.Ct. at 2536-38; NRC 2009*, supra* note 15, at 3-17 to 3-19 (noting that with regard to many problematic forms of forensic science judicial gatekeeping has been "utterly ineffective"); Brandon L Garrett & Peter J. Neufeld, *Invalid Forensic Science Testimony and Wrongful Convictions*, 95 Va. L. Rev. 1, 14 (2009); Erin Murphy, *The New Forensics: Criminal Justice, False Certainty, and the Second Generation of Scientific Evidence*, 95 Calif. L. Rev. 721 (2007); William C. Thompson, *Beyond Bad Apples: Analyzing the Role of Forensic Science in Wrongful Convictions*, 37 Sw. L. Rev. 1027 (2008); William C. Thompson & R. Dioso-Villa, *Turning a Blind Eye to Misleading Scientific Testimony: Failure of Procedural Safeguards in a Capital Case*, 18 Alb. L.J. Sci. & Tech. 151 (2008); Jane Campbell Moriarty, "*Misconvictions," Science, and the Ministers of Justice*, 86 Neb. L. Rev. 1 (2007).

Upon learning from the Mueller Report of the serious deficiencies in the scientific evidence in this case, the District Court found that respondent's right of due process had been violated. The Court of Appeals upheld this ruling. *Amici Curiae* express no opinion about whether these courts followed correct legal procedures in considering the Mueller report and ruling as they did. However, *Amici Curiae* wish to assure this Court that the Mueller report was correct and that a scientific assessment of the testimony fully supports the lower courts' finding that the prosecution's evidence in this case was seriously flawed and that the jury was likely to have been misled. We believe, as a matter of simple fairness, that the problems in this trial need to be remedied whether or not the specific remedy entailed in the rulings of the lower courts is the correct one.

If this Court decides, on procedural grounds, to remand the case for further proceedings, we hope that it will offer a clear discussion of the underlying problems in the scientific evidence, and particularly the confusion of *random match probability* and *source probability*, for the edification and guidance of lower courts. In our opinion, forensic scientists should not be allowed to express opinions about *source probability* when those opinions rest on fallacious reasoning or depend, in part, on the expert's assessment of non-scientific evidence. An authoritative statement from this Court to that effect would help raise awareness of this important issue and thus improve the quality of scientific

testimony. Fallacious, misleading testimony of the type seen in this case should never be allowed in a court of law.

Respectfully Submitted,

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July 24, 2009

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