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Frye after *Daubert*: The Role of Scientists in Admissibility Issues As Seen through Analysis of the DNA Profiling Cases

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In *Daubert v Merrell Dow Pharmaceuticals, Inc.*, the Supreme Court held that the *Frye* rule for admissibility of scientific evidence had been superseded by the adoption of the Federal Rules of Evidence, and thus that "general acceptance" within the appropriate scientific community is not a necessary precondition for admissibility of scientific evidence in federal courts.[1] Although the Federal Rules of Evidence have been adopted either wholly or substantially by over 30 states,[2] several state court decisions have suggested that *Daubert* will not be dispositive in their handling of scientific admissibility issues.[3] Because the *Frye* standard can still be employed at the state court level[4], and because "general acceptance" is one among several factors a trial judge may consider in determining admissibility under *Daubert*,[5] the issue of the role of scientists in analyzing the admissibility of scientific evidence remains an important one. Furthermore, in the history of cases on the admissibility of DNA profiling evidence, one sees a model for cooperative interaction between the scientific and legal communities to properly handle admission of

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[1] *Daubert v Merrell Dow Pharmaceuticals, Inc.*, 113 S Ct 2786, 2793, 2797 (1993); *Frye v United States*, 293 F 1013 (DC Cir 1923).

[2] Graham C. Lilly, *An Introduction to the Law of Evidence* v (West, 2d ed 1987).

[3] *Arizona v Bible*, 858 P2d 1152, 1183 (Ariz 1993); *People v Wash*, 24 Cal Rptr 2d 421, 437 n 9 (Cal 1993), 861 P2d 1107; *Flanagan v Florida*, 625 So2d 827, 829 n 2 (Fla 1993); *Illinois v Mehlberg*, 618 NE2d 1168, 1993 Ill App LEXIS 1201, *71 n 1 (Ill App); *Minnesota v Alt*, 504 NW2d 38, 1993 Minn App LEXIS 757, *21 (Minn App 1993); *New Hampshire v Cressey*, 628 A2d 696, 1993 N.H. LEXIS 83, *5 (NH 1993); *New York v Moore*, 1993 WL 511845 (AD2d); *Washington v Jones*, 1993 WL 497403, *15 n 10 (Wash App).

[4] Michael Hoenig, *The New Reliability Test for Expert Testimony*, NY L J 3 (Jul 12, 1993).

[5] *Daubert*, 113 S Ct at 2797.

novel scientific evidence.

DNA profiling was first proposed as a scientific method for individuation in 1985.[6] Within three years, a state appellate court had upheld the validity of DNA profiling for purposes of inculpation of a criminal defendant.[7] This rapid acceptance of a novel scientific method for inclusive individuation was unprecedented. In the case of analysis by blood typing, there had been a long period during which evidence was admissible for exculpation (exclusion) but not for inculpation (inclusion).[8] In DNA profiling, the sequence was reversed, with much initial focus on inculpation, and little discussion of its power for exculpation.[9]

The blitzkrieg entrance of DNA profiling into the legal system was assisted by a general societal belief in the "can do" powers of biotechnology, probably not unlike beliefs held about atomic energy in the 1950's. More directly, the entrance into the legal system was facilitated by claims of enormous probabilities of individuation in situations in which a match was declared; in the extreme case, odds of 738 quadrillion to 1 against misidentification were declared.[10] Because of its power of individuation, DNA profiling is the single most powerful forensic tool of the 1990s.

Since 1988, the majority of courts have found DNA profiling

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[6] Alec J. Jeffreys, Victoria Wilson and Swee Lay Thein, *Hypervariable 'Minisatellite' Regions in Human DNA*, 314 Nature 67 (Mar 7, 1985): [DNA 'fingerprints'] provide a powerful method for paternity and maternity testing, [and] can be used in forensic applications. . . ."

[7] *Andrews v State*, 533 So2d 841 (Fla Dist Ct App 1988).

[8] Lilly, *Introduction to the Law of Evidence* at 502-03 (cited in note 2). Michael O. Finkelstein, *Statistics for Lawyers* 99 (Springer, 1990).

[9] Although most of the publicity surrounding DNA profiling has arisen over the possibility of false positives in the inculpation (inclusion) of criminal defendants, the test may also be used for purposes of exculpation (exclusion) of criminal defendants or inmates. Kenneth W. Nimmich, chief of the Scientific Analysis Section at the Federal Bureau of Investigation's laboratory in Washington said that about 30% of the DNA tests that they conduct show no match. Jonathan Rabinovitz, *Rape Conviction Overturned on DNA Tests*, NY Times B6 (Dec 2, 1992). On December 1, 1992, the conviction for rape of Terry Kotler was overturned on the basis of exclusionary DNA evidence; Mr. Kotler had served 11 years in prison. Within one week of the release, the victim still maintained Mr. Kotler's guilt. Id. In fact, three DNA tests showed Kotler did not commit the rape, but the first two were kept out of court by prosecutors. Robert Davis, *Fighting Crime, and Convictions, with DNA Genetic Testing on Rise*, USA Today A8 (Jan 4, 1993). A December 21, 1992 Pennsylvania Superior Court decision held that anyone accused of rape has the right to DNA tests. Biotechnology Newswatch 4 (Jan 4, 1993). DNA profiling already has its analogue of the classic blood test exclusion/conviction [*Berry v Chaplin*, 169 P2d 442 (Cal App 1946)], in which a man excluded by DNA profiling was convicted anyway. Jack Ewing, *Connecticut Jury Disregards DNA Test*, Natl L J 9 (Apr 23, 1990).

[10] Eric Lander, *DNA Fingerprinting on Trial*, 339 Nature 501 (1989).

evidence to be admissible.[11] Before *Daubert*, profiling evidence was admitted for purposes of inculpation in jurisdictions using permissive Federal Rules of Evidence standards.[12] Therein, evidence helpful to the jury is admitted as long as its probative value is not substantially outweighed by the danger of unfair prejudice, confusion of the issues, misleading the jury, or undue delay.[13] Other courts admitted DNA profiling evidence under the more restrictive *Frye* or modified *Frye* standards. The *Frye* standard requires general acceptance in the relevant scientific community of both the theory and the technique underlying the scientific test.[14] Some jurisdictions add a third prong to *Frye*, requiring that the testing laboratory perform the correct scientific procedures in the particular case.[15]

Resistance to the admissibility of DNA profiling later developed in *Frye* or modified *Frye* jurisdictions.[16] The resistance first formed around issues about the quality of experiments performed in individual laboratories and extended to certain assumptions within the theory that were used in the calculation of probabilities.[17] By placing the decision-making burden on the relevant

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[11] As of October, 1991, thirteen state supreme courts had ruled on admissibility of DNA profiling; eight rulings were favorable, three were inconclusive, and two were somewhat negative. Nancy Montgomery, *Russel Murder Trial Sets a Precedent with Use of DNA Test*, Seattle Times E1 (Oct 14, 1991). The Supreme Court of Hawaii noted that as of March 27, 1992, of 38 reported DNA decisions, only six have found profiling evidence inadmissible. *State v Montalbo*, 828 P2d 1274, 1283 n 7 (Hawaii 1992).

[12] *United States v Jakobetz*, 747 F Supp 250 (D Vt 1990), aff'd 955 F2d 786 (2d Cir), cert denied 113 S Ct 104 (1992). The district court admitted DNA profile evidence under the Federal Rules of Evidence standard, and the Second Circuit affirmed and indicated that the *Frye* standard would also be satisfied. See also *State v Brown*, 470 NW2d 30 (Iowa 1991) (court applied state rules of evidence standards to admit DNA profiling).

[13] FRE 403.

[14] *Frye v United States*, 293 F 1013 (DC Cir 1923).

[15] California uses the *Kelly/Frye* test in which "the proponent of the evidence must demonstrate that correct scientific procedures were used in the particular case." *People v Kelly*, 17 Cal 3d 24, 30, 549 P2d 1240, 1244, 130 Cal Rptr 144, 148 (Cal 1976). In the specific context of DNA profiling, a third prong to *Frye*, involving lab procedure, was added in *People v Castro*, 144 Misc 2d 965, 545 NYS2d 985 (Super Ct 1989).

[16] The pivotal case questioning the accuracy of laboratory results of DNA profiling is *Castro*, 545 NYS2d at 985.

[17] *State v Schwartz*, 447 NW2d 422 (Minn 1989); both Frye and the Federal Rules of Evidence were used to exclude DNA evidence in *Commonwealth v Curnin*, 409 Mass 218, 565 NE2d 440 (Mass 1991). The epic battle was *United States v Yee*, 134 FRD 161 (N D Ohio 1991), aff'd 1993 US App LEXIS 32574 (6th Cir). Although the DNA evidence was admitted, the opponents published their arguments in 254 Science 1745 (1991), which was extensively quoted in *United States v Porter*, 618 A2d 629 (DC 1992). Using the *Kelly/Frye* standard, California admitted DNA profiling evidence for inculpation in *People v Axell*, 235 Cal App 3d 836, 1 Cal Rptr 411 (1991). However, after the Lewontin/Hartl paper and the NRC report on DNA profiling, see note 18 and accompanying text, California refused

scientific community with regard to questions of admissibility of scientific theories or techniques, the *Frye* standard creates a restoring force through which the legal system is pointed in the direction of the proper scientific result. In the context of DNA profiling, this restoring force was manifested in the publication entitled "DNA Technology in Forensic Science" by the National Research Council of the National Academy of Sciences.[18] Although the results of this report are not accepted by all sides,[19] the report establishes a set of minimum standards under which criminal defendants may be judged in the period during which significant scientific agreement does not exist. Under *Frye*, this report serves as a readily obtainable measure of the scientific consensus on DNA profiling. Thus, a compromise is obtained between the prosecutor who needs the valuable scientific tool and the defendant who might be unfairly prejudiced by hyperbolic claims of accuracy.

This comment argues that the acceptance of a relevant scientific community *should* be a "necessary precondition to the admissibility of scientific evidence."[20] The *Frye* standard, in explicitly requiring general acceptance in the appropriate scientific community of both the theory and technique, is superior to the more general, multi-factored Federal Rules of Evidence standards, including the one espoused in *Daubert*. Moreover, novel scientific evidence should not be admitted unless the methods actually employed by the specific laboratory are routinely

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to admit DNA profiling evidence for inculpation in *People v Barney*, 8 Cal App 4th 798, 825, 10 Cal Rptr 2d 731 (1992); *People v Howard*, 8 Cal App 4th 798, 10 Cal Rptr 2d 731 (1992): "We conclude the admission of the DNA analysis evidence in the present cases was error for two reasons: (1) the absence of general scientific acceptance as to the statistical calculation process, and (2) the lack of the third prong inquiry." See also *People v Wallace*, 14 Cal App 4th 651, 17 Cal Rptr 2d 721 (1993).

[18] In *United States v Porter*, 618 A2d 629 (DC 1992), the District of Columbia Court of Appeals admitted profiling evidence, but suggested that probabilities might be used only to the extent that the requisite consensus existed. The court relied heavily on the report of the National Research Council of the National Academy of Sciences entitled *DNA Technology in Forensic Science*, which was released in April, 1992. Committee on DNA Technology in Forensic Inference, *DNA Technology in Forensic Science* (National Academy, 1992). ("the NRC report"). See also Leslie Roberts, *DNA Fingerprinting: Academy Reports*, 256 Science 300 (Apr 17, 1992). On the other side of the coin stands *Commonwealth v Teixeira*, in which a Superior Court Judge in Massachusetts ruled DNA evidence admissible because of the NRC report and in spite of the holding on inadmissibility in *Commonwealth v Curnin*. Dick Dahl, *DNA 'Matching' Tests Admissible, Judge Rules; New Statistical Technique Key to Ruling*, Massachusetts Lawyers Weekly 46 (Dec 7, 1992).

[19] B. Devlin, Neil Risch, and Kathryn Roeder, *Statistical Evaluation of DNA Fingerprinting: A Critique of the NRC's Report*, 259 Science 748 (1993).

[20] *Daubert*, 113 S Ct at 2799.

capable of giving the result of the generally accepted technique.[21]

Therefore, this paper has two goals: first, to illustrate, through DNA profiling, the role of the scientific community in deciding questions of admissibility of scientific theories or techniques; and second, to argue that the *Frye* standard, by establishing general acceptance of the scientific theory or technique as an absolute prerequisite for admissibility, is superior to the Federal Rules standards.

This paper is divided into three parts. Part I defines the legal standards for admitting novel scientific evidence into the courtroom. Part II defines the components of the DNA profiling method and identifies those areas in which conflict has developed. Part III presents arguments for the use of the *Frye* standard.

I. STANDARDS FOR ADMISSIBILITY: *FRYE* VERSUS *DAUBERT*

Benchmark evidentiary standards emanate from *Frye* and the Federal Rules of Evidence. The intrinsic distinction is that scientists assess the validity of techniques in *Frye* while judges determine the reliability of techniques in the standards based on the Federal Rules.

A. The *Frye* Standard

In 1923, the Court of Appeals for the District of Columbia Circuit ruled that polygraph evidence could not be used to exculpate a defendant because no generally accepted scientific theory supported the test.[22] As a result, evidence from lie detectors was inadmissible for purposes of both inculpation (inclusion) and exculpation (exclusion).

The key aspects of what has become the *Frye* standard are contained within a single paragraph:

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[21] This position is in tension with the conclusion of Comment, *The Admissibility of DNA Typing: A New Methodology*, 79 Georgetown L J 313 (1990). Therein, both the *Frye* test and the Federal Rules of Evidence test (termed McCormick's relevancy approach) are rejected in favor of the *Downing* test, in which reliability, rather than probative value, is balanced against prejudicial effect. *United States v Downing*, 753 F2d 1224 (3d Cir 1985). The *Downing* analysis is mentioned with favor in *Daubert*. *Daubert*, 113 S Ct at 2797.

[22] *Frye v United States*, 293 F 1013 (DC Cir 1923), superseded by statute as stated in *Daubert v Merrell Dow Pharmaceuticals, Inc.* 113 S Ct 2786 (1993).

> Just 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 the 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 to which it belongs.[23]

The *Frye* test is considered to have two parts. First, there must be a theory that is generally accepted in the appropriate scientific community. The general acceptance of the theory serves as a proxy for the existence of valid scientific principles underlying the theory. Second, there must be methods, implementing the theory, which are generally accepted in the appropriate scientific field. The general acceptance of methods serves as a proxy for the existence of a valid and reliable scientific technique to utilize the theory in practice.

The traditional arguments in favor of the *Frye* standard are that it allows disputes about scientific validity to be resolved by the pertinent scientific community, spares the courts the time-consuming, difficult tasks of assessing scientific developments, and protects the trier of fact from its likely predisposition to find all scientific results to be accurate and reliable.[24]

As applied by many state courts, the *Frye* test asks two questions to establish admissibility of the evidence. According to the *Castro* court, these two prongs of *Frye* are:[25]

> 1. Is there a theory that is generally accepted in the scientific community which supports the conclusion that the scientific test can produce reliable results?
> 2. Are there techniques and experiments that currently exist that are capable of producing reliable results which are generally accepted in the scientific community?

Additionally, to deal with concerns about *Frye*'s inadequacy with respect to highly complex procedures, the *Castro* court included a third prong which related to the experimental procedure used in the specific case:[26]

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[23] *Frye*, 293 F at 1014.

[24] Lilly, *Introduction to the Law of Evidence* at 495 (cited in note 2).

[25] *Castro*, 545 NYS2d at 987-88.

[26] The *Castro* court noted that while the first two prongs of the test represented the

> 3. Did the testing laboratory perform the accepted scientific technique?

Although this third prong has been adopted by some courts analyzing admissibility of DNA profiling,[27] other courts[28] and some commentators have been critical:

> The *Castro* court's compromise is problematic, however, because questions regarding the reliability of particular procedures go to the weight, not the admissibility, of the DNA evidence. While the conflict of authority on this issue is well-recognized, both eminent commentators and many courts have taken the position that questions regarding procedures go to weight, not admissibility.[29]

The conventional two-prong *Frye* test has ambiguities:

> 1. What must be generally accepted, the underlying principle or the application?
> 2. What is the appropriate community?
> 3. How much agreement constitutes general acceptance?
> 4. What defines the reach of *Frye*?

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essential inquiries under *Frye*, the third prong constituted a separate and independent test, warranting its own pretrial inquiry. *Castro*, 545 NYS2d at 988.

[27] *United States v Two Bulls*, 918 F2d 56, 61 (8th Cir 1990); *Ex parte Perry*, 586 So2d 242, 248 (Ala 1991); *Commonwealth v Rodgers*, 605 A2d 1228, 1234 (Pa Super 1992); *People v Lindsey*, 1993 Colo App LEXIS 2, *11-12 (Colo App 1993).

[28] The clearest rejection appears in *State v Cauthron*, 120 Wash 2d 879, 846 P2d 502, 1993 Wash LEXIS 56, *18-19: "The *Castro* analysis is inappropriate in jurisdictions utilizing the *Frye* standard of admissibility. The core concern of *Frye* is only whether the evidence being offered is based on established scientific methodology. This involves both an accepted theory and a valid technique to implement that theory. . . . If the particular technique is sufficiently accepted in the scientific community at large, any remaining concerns about the possibility of error or mistakes being made in the case at hand can be argued to the factfinder." Additionally, New York courts rejected the *Castro* analysis in *People v Moore*, 1993 WL 511845 (NYAD), *People v Mohit*, 153 Misc 2d 22, 579 NYS2d 990, 992 (Westchester County Ct 1992) and in *People v Wesley*, 589 NYS2d 197 (App Div 1992), 183 A2d 75. Arguably, *State v Montalbo*, 828 P2d 1274 (Hawaii 1992) holds that challenges to test results go to weight. Two other cases suggest only that the third prong of *Castro* is not part of *Frye*. Although applying only a two prong analysis, the court in *State v Ford*, 301 SC 485, 392 SE2d 781, 784 (SC 1990), cited *Castro* favorably in stating that the admissibility of DNA test results remains subject to attack. Similarly, the court in *State v Vandebogart*, 136 NH 365, 616 A2d 483 (NH 1992) did not consider the third prong of *Castro* part of *Frye*, but did acknowledge that the admissibility of test results could be challenged.

[29] Comment, 79 Georgetown L J at 329 (cited in note 21). Footnotes omitted.

Although Commentators in the DNA profiling area have criticized *Frye* as poorly suited to the complexities of DNA analysis,[30] the mere presence of the *Frye* questions assures that the complexities of the analysis will be contemplated. At the very least, *Frye* gives the scientific community some time to reflect upon the novel method and remove deficiencies that may exist. Although judicial tribunals are deprived of potentially useful scientific evidence during this waiting period, the *Frye* mandate requires that a theory and/or technique for which general acceptance does not exist should not be used. In contexts in which there is a criminal defendant, as the case with *Frye* and with most DNA profiling cases, there is a high standard of proof, a situation somewhat different than *Daubert*, which was a civil case.[31]

B. The Federal Rules of Evidence Standards

1. Pre-*Daubert*.

The Federal Rules of Evidence discuss scientific evidence in Rule 702, which requires that scientific, technical, or other specialized knowledge assist the trier of fact to understand the evidence.[32] This "helpfulness standard" might be thought to conflict with *Frye*'s austere general acceptance test. Prior to *Daubert*, there was uncertainty over whether or not the *Frye* test survived the enactment of the Federal Rules of Evidence in 1975.[33] In the discussion preceding the adoption of the Federal Rules of Evi-

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[30] Comment, *Beyond* People v. Castro: *A New Standard for Admissibility for DNA Fingerprinting*, 7 J Contemp Health L & Policy 269, 270 (1991); Comment, *DNA Fingerprinting: Is it Ready for Trial*, 45 U Miami L Rev 243 (1990).

[31] Furthermore, in the criminal arena, the law enforcement establishment will be the proponent of the technique which is used repeatedly against unrelated individual defendants, while in many civil cases the individual plaintiff (or perhaps a class of plaintiffs) will be the proponent of the technique against a "deep pockets" defendant in nominally a single episode. While the liberal policy of *Daubert* will benefit civil plaintiffs, this policy will work to the disadvantage of criminal defendants during the transitional period in which a technique is not optimized. Although a technique such as DNA profiling should be neutral, in the sense that it can inculpate or exculpate, profiling was in fact used more by law enforcement institutions for inculpation than by individuals for exculpation.

[32] Federal Rule of Evidence 702 states: "If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise."

[33] *Christophersen v Allied Signal Corporation*, 939 F2d 1106, 1120 (5th Cir 1991) (The court applied a combined *Frye* and Federal Rules of Evidence standard. The concurring opinion questioned whether *Frye* had survived the enactment of the Federal Rules. *Christopherson* is disapproved by *Daubert*, 113 S Ct 2786.

dence, there was little consideration of the subject of scientific evidence.[34] Furthermore, the Advisory Committee Note to Rule 702 does not mention *Frye*'s general acceptance test. If *Frye* was merely a rule of evidence, and not a substantive rule, many scholars did not believe that it did survive.[35] The use of *Frye* in the Federal courts was sporadic after the adoption of the Federal Rules of Evidence. In the area of voiceprint identification, *Frye* was invoked to block admission in *United States v McDaniel,*[36] but Rule 403 allowed admissibility in *United States v Baller*[37] and in *United States v Williams.*[38]

Under *United States v Williams*, the Federal Rules approach involved a balancing test that weighs the probativeness,[39] materiality,[40] and reliability of the evidence against the tendency to mislead or confuse the jury, or unfairly prejudice the defendant.[41] The specific legal meaning of "reliability" is that a correct answer is sufficiently probable for a given situation.[42] The term reliability thus imports the scientific concepts of accuracy ("correct") and precision ("sufficiently probable"). In the case of a scientific technique, there are several factors to consider to establish reliability of a technique:

1. the potential rate of error,
2. the existence and maintenance of standards,
3. the care with which the scientific technique has been employed and whether it is susceptible to abuse,
4. whether there are analogous relationships with other types of scientific techniques that are routinely admitted

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[34] Federal Rules of Evidence for United States Courts and Magistrates 374 (West, 1992).

[35] *Christophersen*, 939 F2d at 1120; see also 22 C. Wright and K. Graham, *Federal Practice and Procedure* § 5168 at 89-90 (1978). For another issue of statutory construction, see the analysis of the doctrine of abandonment in *Midlantic National Bank v New Jersey Department of Environmental Protection*, 474 US 494, 500-01 (1986).

[36] *United States v McDaniel*, 538 F2d 408, 412-13 (DC Cir 1976).

[37] *United States v Baller*, 519 F2d 463, 466 (4th Cir 1975).

[38] *United States v Williams*, 583 F2d 1194 (2d Cir 1978).

[39] Probative evidence is that which furnishes, establishes, or contributes toward proof. Probative evidence is relevant. Relevant evidence makes the existence of any fact that is of consequence to the determination of the action more probable or less probable than it would be without the evidence. FRE 401.

[40] Material evidence is evidence which is important to the question in controversy, and which must necessarily enter into the consideration of the controversy, and which by itself or in connection with other evidence is determinative of the case.

[41] *Williams*, 583 F2d at 1198.

[42] *Christophersen*, 939 F2d at 1111 (citing Bert Black, *A Unified Theory of Scientific Evidence*, 56 Fordham L Rev 595 (1988)).

into evidence,
5. the presence of failsafe characteristics.[43]

Depending upon what balances of factors one chooses to make, one can get different tests for admissibility from the Federal Rules of Evidence. The most generous reading of Rules 401 on relevant evidence,[44] 403 on exclusion of relevant evidence,[45] and 703 on expert opinions based on otherwise inadmissible hearsay,[46] leads to McCormick's relevancy test: "[a]ny relevant conclusions supported by a qualified expert witness should be received [into evidence] unless there are reasons for exclusion."[47] A recent commentator argued that the test articulated in *United States v Downing*[48] is more stringent, and is superior to both *Frye* and McCormick's relevancy test for determining admissibility of DNA evidence.[49] Unlike the relevancy test, the *Downing* test balances reliability, not probative value, against prejudicial effect.[50] Unlike *Frye*, the *Downing* test considers the given method's relationship to more established scientific procedures, the existence of scientific literature evaluating the technique, and the frequency with which the technique leads to erroneous results.[51]

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[43] *Jakobetz*, 747 F Supp at 254, quoting *Williams*, 583 F2d at 1198-99. Failsafe procedures are designed to prevent malfunctioning through an intricate system of protective devices; ideally, they would thwart human error. But see Eugene Burdick and Harvey Wheeler, *Failsafe* (McGraw-Hill, 1962).

[44] Rule 401 states: "'Relevant evidence' means evidence having any tendency to make the existence of any fact that is of consequence to the determination of the action more probable or less probable than it would be without the evidence."

[45] Rule 403 states: "Although relevant, evidence may be excluded if its probative value is substantially outweighed by the danger of unfair prejudice, confusion of the issues, or misleading the jury, or by considerations of undue delay, waste of time, or needless presentation of cumulative evidence."

[46] Rule 703 states: "The facts or data in the particular case upon which an expert bases an opinion or inference may be those perceived by or made known to the expert at or before the hearing. If of a type reasonably relied upon by experts in the particular field informing opinions or inferences upon the subject, the facts or data need not be admissible in evidence."

[47] C. McCormick, *McCormick on Evidence*, § 203 at 608 (West, 3d ed 1984).

[48] *United States v Downing*, 753 F2d 1224 (3d Cir 1985).

[49] Comment, 79 Georgetown L J at 331 (cited in note 21).

[50] Furthermore, in the *Downing* test reliability is weighed directly against prejudice, while in relevancy, probative evidence must be substantially outweighed by prejudice to be rendered inadmissible.

[51] Although the *Downing* test is more stringent than the relevancy test, it asks fewer questions than *Williams*. Since scientists would consider the four *Downing* factors (as well as others) in forming their *Frye* judgment, the real question remains: who interprets the data, scientists or judges?

2. *Daubert* v *Merrell Dow.*

Daubert held that *Frye* was superseded by the adoption of the Federal Rules of Evidence. The remaining question before the *Daubert* Court was, which Rules? First, Rule 402, which "provides the baseline," and more specifically, Rule 702, which governs expert testimony, are the sources from which the Court fashions "some general observations" to structure the trial judge's inquiry.[52]

Under *Daubert*, the judge, rather than the relevant scientific community, is the final arbiter over any dispute over the admissibility of scientific evidence. In this role, the judge is guided primarily by Rule 702 and also by Rules 703-706. Rule 702 spells out the trial judge's obligation: "[i]f scientific, technical or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue . . . [an expert] may testify thereto. . . ." According to *Daubert*, therefore, "'[s]cientific knowledge' establishes a standard of evidentiary reliability," while, the requirement that the evidence assist the trier of fact "goes primarily to relevance."[53]

However, unlike the previous articulation of the Federal Rules standard in *Williams*, the trial judge must make an initial determination as to the relevance and reliability, pursuant to Rule 104(a), which entails "a preliminary assessment of whether the reasoning or methodology underlying the testimony is scientifically valid. . . ."[54] The Court set out some general guidelines for the trial judge to follow in making this initial determination of scientific validity. These are: "whether a theory or technique can be (and has been) tested," "whether the theory or technique has been subjected to peer review and publication," consideration of the "known or potential rate of error . . . and the existence and maintenance of standards controlling the technique's operation." The Court also notes that, in this inquiry, "[g]eneral acceptance . . . can . . . have a bearing on the inquiry."[55] The Court concludes by stating that the "[o]verarching subject is the scientific validity—and thus the evidentiary relevance and reliability—of the principles that underlie a proposed submission."[56] The

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[52] *Daubert*, 113 S Ct at 2796.

[53] Id at 2795.

[54] Id at 2796.

[55] Id at 2797.

[56] Id.

Daubert court emphasized the flexibility of this inquiry[57] and expressed no preference among several approaches.[58]

There are thus two major practical differences between the Federal Rules based standard articulated in *Daubert* and the *Frye* standard which is imposed against the background Federal Rules. First, in *Daubert*, general acceptance by the relevant scientific community is not an absolute prerequisite for the admissibility of scientific evidence—in *Frye*, it is. Second, since it is not, and since a technique's validity must still be ascertained, the trial judge is given a laundry list of factors with which to screen for scientific validity. Therefore, the trial judge, and not a relevant scientific community, is the real referee over scientific validity. Furthermore, the inquiry itself is different. In applying the *Daubert* factors to analyze specific scientific evidence, the trial judge is looking only for certain manifestations of validity, rather than inspecting the cogency of reasoning underlying the evidence, as would be done by scientists under *Frye*.

3. Criticism of the Federal Rules Standards.

The issue with the various Federal Rules approaches is amorphous structure: various laundry lists of factors are combined in arbitrary ways by nonexperts to produce unknown probabilities of accuracy to be balanced against unmeasured prejudices. Moreover, a serious difficulty arises in situations for which the only information available may be the information of the proponent. The only way to validate the technique and the specific data obtained from the technique will be through information supplied by the proponent of the evidence. Although *Daubert* assigns the trial judge with the responsibility for assessing the scientific validity of the technique, it does not provide the means to make this assessment. In the absence of sources independent of the proponent, the judge has no way to truly assess validity or reliability.

Consider an example. Suppose that there were only one laboratory in the world that purported to measure the weight percentage of carbon in diamond by burning the carbon of diamond to carbon dioxide. The technique gave a result of (99.5±0.1) wgt% carbon. The reproducibility was excellent, standards were

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[57] *Daubert*, 113 S Ct at 2790, 2797.

[58] "To the extent that they focus on the reliability of evidence as ensured by the scientific validity of its underlying principles, all these versions may well have merit, although we express no opinion regarding any of their particular details." Id at 2797.

maintained, great care was exercised, the technique was similar to known techniques, and many papers were published. All the manifestations of reliability were present. This is sufficient to prove precision, but it does not prove accuracy. There could have been systematic error. Maybe there was incomplete combustion and the true number is 100 wgt% carbon. Maybe there were impurities and the true number is 99 wgt% carbon. There is simply no way of knowing whether the number is accurate in the absence of independent confirmatory analyses.[59]

To establish the accuracy of the number, inquiry would have to be made into the validity of the technique. A difficulty with the approach of the Federal Rules is its emphasis on probativeness and reliability, very pliable legal concepts, in preference to a real inquiry into validity, a concept which reaches the visceral scientific merit of the method and which, as such, underlies the *Frye* approach.[60] A proponent will always introduce the "best data" available to show that the technique is reliable, in the sense that the answers obtained are accurate and precise. To insure that the science is indeed good science, the court must look beyond empirical results, which in fact may be not only hyperbolic, but also contested, to get to the underlying reasoning of the theory and method. While *Daubert* allows for this inquiry, it is one clearly beyond the competence of the trial judge to make. The court should look to the scientists to explicate the issues. The difficulty with the Federal Rules approaches is that only the trial judge stands as a filter against bad science; in practice, then, an articulate, but scientifically incompetent, proponent can successfully introduce most evidence.

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[59] As discussed below, one way to get at the accuracy of scientific techniques is to submit samples of composition known to the submitter, but not to the analyzer. Preferably, the analyzer should be unaware that a control test is being done, so that the sample is treated with the same care as a routine sample.

[60] A validity issue defeated the DNA evidence of Lifecodes in the "false positive" case of *Maine v McLeod*. Colin Norman, *Maine Case Deals Blow to DNA Fingerprinting*, 246 Science 1556 (Dec 22, 1989). The refusal of the court in *United States v Yee*, 134 FRD 161 (N D Ohio 1991) to deal with issues of validity led to the publication of Richard C. Lewontin and Daniel L. Hartl, *Population Genetics in Forensic DNA Typing*, 254 Science 1745 (Dec 20, 1991), which in turn may have affected the final NRC report which came out in April 1992.

II. THE SUPERIORITY OF *FRYE* AS SEEN THROUGH THE EXAMPLE OF DNA PROFILING

The use of *Frye* in the federal courts was sporadic after the adoption of the Federal Rules of Evidence. In DNA profiling cases, the evidentiary standards for admissability were hybrids. In the first Federal Court of Appeals holding on DNA profiling in *United States v Two Bulls*, the court's final order was[61]

> The trial court is to decide
> (1) whether DNA evidence is generally accepted by the scientific community,
> (2) whether the testing procedures used in this case are generally accepted as reliable if properly performed,
> (3) whether the test was performed properly in this case,
> (4) whether the evidence is more prejudicial than probative in this case, and
> (5) whether the statistics used to determine the probability of someone else having the same genetic characteristics is more probative than prejudicial under Rule 403.

In the second Federal Court of Appeals holding on DNA profiling in *United States v Jakobetz*, the court noted that the District Court's findings "would satisfy not only the *Frye* standard, but the *Two Bulls* and *Castro* standard as well."[62]

The report by the National Research Council of the National Academy of Sciences on *DNA Technology in Forensic Science* sets guidelines for testing which may render court decisions more uniform. In a decision made after the release of the report, the District of Columbia Court of Appeals applied a pure *Frye* standard to admit the DNA profiling evidence and to suggest that probabilities for which the requisite consensus exists would be admissible.[63] The scientific analysis that formed the conclusions of this report is discussed in this section. This is done both to demonstrate the process of establishing validity in the scientific

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[61] *United States v Two Bulls*, 918 F2d 56, 61 (8th Cir 1990).

[62] *United States v Jakobetz*, 955 F2d 786, 799 (2d Cir 1992). Although the district court below had considered only the Federal Rule-based *Williams* standard, the Court of Appeals made the conclusion that profiling passed *Frye*. The *Jakobetz* decision came out in the time window between the December 20, 1991 issue of Science (which made clear that DNA probability assessments were not accepted by all scientists) and the April 1992 release of the NRC report (which advocated a conservative approach to probabilities). The admissibility standard of *Jakobetz* is analyzed in Comment, *Admissibility of Forensic DNA Profiling: A Movement away from* Frye, 44 Wash U J Urb & Contemp L 211 (1993).

[63] *United States v Porter*, 618 A2d 629, 633-36 (DC 1992).

community and to illustrate the difficulty a trial judge may have in reaching any accurate conclusion without such a rigorous procedure.

In the following, basic concepts are introduced in section A, scientific issues involved in the match component of DNA profiling are in section B, and scientific issues involved in the probability component of DNA profiling are in section C.

A. Basic Concepts

Before going into the details of DNA profiling, one must recognize that there are two distinct components of the method: defining the existence of a match and assessing the probabilistic significance of the match.

In the matching component in a criminal case, one is comparing DNA evidence from the crime scene to DNA evidence obtained from the suspect (or possibly the victim) to see if they match. In a typical example involving the crime of rape, one would compare the DNA of the semen found at the crime scene to DNA from the blood of the suspect. The matching component of DNA profiling is a complicated experimental procedure involving several steps. Experimental errors can be made both within the taking of the DNA samples[64] and through the experimental manipulation of the DNA samples.[65]

If the two samples of DNA do not match, the suspect is exculpated. This outcome occurs in practice about 30% of the time.[66] If a match is found, the suspect is inculpated, and one

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[64] For example, the DNA sample at the crime scene may have deteriorated through environmental exposure, or there may be confusion because of the presence of DNA of several different humans, not all of whom are identified.

[65] The DNA of the crime scene sample might have been affected by ambient agents so that it appears to be different in electrophoresis than if it were not so affected. Thus, chemical or biological entities might have already cut the DNA transverse to its length axis before the restriction fragment length polymorphism ("RFLP") enzyme (see notes 67-68 and accompanying text) was added, so that the fragments appear smaller than they should be. Or, chemical entities might have inserted ("intercalated") between the base pairs (see section II.A.1. below), so that the fragments appear larger than they should be. Separately, there might be variations in the experimental conditions themselves: non-uniform electrophoresis plate or uneven film expansion. These factors tend to make something that was a match appear not to be a match. However, acceptance of such variability might lead to a tendency to accept slightly non-matching data as being a match. See the discussion of *Maine v McLeod* in Norman, 246 Science at 1556 (cited in note 60). Also, there is current debate about the inculpation of David Hicks on the basis of DNA profiling. William B. Falk, *DNA and Truth; Genetic 'Fingerprint' Can be Smudged by Human Error*, Newsday 7 (Dec 7, 1992).

[66] Kenneth W. Nimmich, chief of the Scientific Analysis Section of the FBI, as quoted

continues to the second component of the DNA profiling method. Here, the experimental result is compared to databases of DNA profiles to determine how likely a second person, other than the suspect, would have DNA which would match that of the crime scene. This second component of DNA profiling involves no additional laboratory work, although it does involve utilization of theories of statistics and population genetics.

1. DNA structure.

The genetic information of an individual is encoded in the person's DNA (deoxyribonucleic acid). The manner of this encoding is structural, specifically determined by sequences of fundamental subunits. No two individuals, other than identical twins, have the same DNA.

A simplistic model of the structure of DNA is a ladder. The poles of the ladder are made of a sugar-phosphate backbone. The rungs are the critical feature, and each rung is composed of a pair of molecules referred to as a base pair. Genetic information is conveyed in the sequence of base pairs along the ladder. Although in the real world the DNA ladder is curved to form a helix, the simple, two-dimensional ladder model is sufficient to understand the basics of the chemistries involved in the match component of profiling.

There are only four molecules involved in the rungs of the ladder: adenine (A), guanine (G), thymine (T), and cytosine (C). Furthermore, adenine pairs only with thymine, and guanine pairs only with cytosine, so that the only rungs that can exist are A-T or G-C.

Certain processes associated with DNA profiling can be easily envisioned in terms of the ladder model. There are two obvious ways in which one could symmetrically break down the ladder. One could cut the poles transverse to the length axis, thereby making shorter ladders. Or, one could cut the rungs longitudinally (between the A-T or G-C bonds) to form two half-ladders, each having only a single pole. Not surprisingly, biologists do both.

Restriction enzymes, which are employed in the typical restriction fragment length polymorphism (RFLP) profiling method,[67] cut the DNA transverse to the ladder axis at known points

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by Jonathan Rabinovitz, *Rape Conviction Overturned on DNA Tests*, NY Times B6 (Dec 2, 1992).

[67] The other technique used for forensic DNA analysis is polymerase chain reaction (PCR), a subject of the Nobel Prize in Chemistry in 1993. The idea behind PCR is to make

on the ladder; this converts the large DNA ladder into smaller DNA ladder fragments.

In contrast, denaturing splits the DNA ladder down the length axis, so that one ends up with two molecules, each containing one pole attached to a set of individual bases. More simply, the denaturing process can also be envisioned as unzipping a zipper. If one knew the identity of one such single-pole (or half-zipper) entity, one could predict the sequencing of bases in its conjugate. Since one can have only A-T or G-C pairs, the presence of an A at a particular point in one molecule would require a T to exist at the same point in the conjugate. To expand, if one found a fragment AAAGGTTTT, one would know the conjugate to be TTTCCAAAA.

One can envision the basics of DNA profiling by reference to the ladder model. First, longitudinal and transverse cuts are made, so that one obtains a mixture of short, half-ladders. Then, one adds to this mixture a half-ladder of a very specific base sequence (the "probe"), which will reform a short ladder fragment only with its conjugate sequence. In this hybridization step of RFLP analysis, the probe is typically radioactively labeled so that the resultant reformed short ladder fragment can be identified. By varying the base sequence of the probe, the scientist analyzes different base sequences of the DNA.

Although the full DNA structure is not adequately represented by a ladder,[68] the ladder model can illustrate the awesomeness of the DNA molecule. The human DNA ladder is composed of 3 billion rungs. If unfolded, the DNA from a single cell would be about 1.5 meters in length, and the total DNA from a human body would stretch 93 billion miles. However expansive these numbers are, one must note that DNA profiling deals with only a small fraction of the DNA molecule, and does not purport to match one molecule with another molecule. If the entirety of the

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many copies of a given fragment; thus, the test has advantages over RFLP when there is little DNA sample available. The technique is described by George F. Sensabaugh and Cecilia von Beroldingen, *The Polymerase Chain Reaction: Application to the Analysis of Biological Evidence*, in Mark A. Farley and James J. Harrington, eds, *Forensic DNA Technology* at 63-82 (Lewis, 1991). The PCR test is available through Cetus Corporation; the PCR technology was adopted by the Suffolk County, New York crime lab in 1992. Falk, Newsday at 7 (cited in note 65). Labs employing the more common RFLP tests may save some crime scene DNA sample for PCR testing. Michael L. Baird, *Analysis of Forensic DNA Sample by Single Locus VNTR Probes* in Farley and Harrington, eds, *Forensic DNA Technology* at 39.

[68] Jan A. Witkowski, *Milestones in the Development of DNA Technology*, in Farley and Harrington, eds, *Forensic DNA Technology* at 1-23 (cited in note 67).

molecule were analyzed, one would reach only the first component of the DNA profiling method, and the theoretical assumption of DNA uniqueness would render the probabilisitic analysis of the second component unnecessary. That is, if there were a match of every base pair between crime scene DNA and suspect DNA, the fundamental assumption of DNA uniqueness would prove inculpation. It is because every base pair is not analyzed that probabilistic analysis is undertaken.

2. Nomenclature.

Thus, although individuation by DNA analysis has been referred to as "fingerprinting,"[69] such terminology is falling into disfavor because of the inaccuracy of the analogy between DNA profiling and traditional fingerprinting.[70] Approximately 99% of the three billion base pairs of DNA are in the same sequence for all humans and thus are not useful for individuation. DNA profiling takes advantage of the presence of that small fraction of DNA which is not equivalent for all humans.

An image of DNA profiling as the lining up of two fingerprint images on a screen, which might be conveyed by the term "DNA fingerprinting," is misleading.[71] Of the one percent of the DNA which is variable among humans, only a small fraction is ever analyzed, so that DNA profiling involves investigation of only a minority of a minority of the base sequences of the DNA.

Even within this limit, one notes that the regions used for profiling, although *not* identical for all humans, are identical among *some* humans. Individuation is accomplished by analyzing several different regions of the DNA molecule. Declaring a match is somewhat akin to identifying a suspect as the perpetrator because suspect and perpetrator have many common traits: brown hair, blue eyes, a wart on the nose, a dueling scar on the cheek. In DNA profiling, the DNA of the suspect and perpetrator are compared at only a few sites on the DNA molecule.

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[69] Comment, 45 U Miami L Rev 243 (cited in note 30); Comment, 7 J Contemp Health L & Policy at 269 (cited in note 30).

[70] Note, *The Dark Side of DNA Profiling: Unreliable Scientific Evidence Meets the Criminal Defendant*, 42 Stan L Rev 465 n 3 (1990); Lewontin and Hartl, 254 Science at 1745 (cited in note 60); Edward Humes, *The DNA Wars*, LA Times 20 (Nov 29, 1992).

[71] Nevertheless, as with fingerprints, a database is being developed. The FBI laboratory is working with the states to develop the combined DNA index system (CODIS), a national DNA database. William Sessions, prepared statement to Subcommittee on Civil and Constitutional Rights, House Committee of the Judiciary, Federal News Service (Mar 25, 1993).

B. Identification of Issues in the Matching Component of Profiling

1. More detailed terminology.

In profiling, the DNA molecule is cut, transverse to the ladder axis, into smaller pieces called fragments. To focus on individuation, the molecule is cut at very specific points, to yield (some) fragments that are different for most individuals. The cutting is done by a restriction enzyme (also called restriction endonuclease) and the portion of the DNA which is cut out which is variable among humans is thus called a restriction fragment length polymorphism (RFLP).

At present, DNA profiling done by the commercial laboratories Lifecodes and Cellmark, and by the FBI, uses variable regions that occur on only one site (or locus) of the DNA molecule. These fragments are referred to as variable number tandem repeats (VNTRs) or minisatellites. The fragments are composed of a fundamental core, made up of from 9-64 base pairs, which is tandemly repeated. There is variability among humans in the sense that a fundamental building block (core) is repeated a different number of times for different people. One has the relationship:

molecular weight of total fragment =
(number of repeated units) X (molecular weight of unit).

A given VNTR fragment is said to be polymorphic, with different individuals having different numbers of the fundamental unit.

However intricate the experimental details, the conceptual design of DNA profiling is relatively simple. A given DNA specimen is cleaved with a restriction length enzyme to create fragments. A sample of the fragment solution is placed on an electrophoresis plate, and an electric field is applied. Because the fragments are electrically charged, they move under the presence of the field. The lower in molecular weight the fragment, the further it will move down on the plate in a given period of time. The fragments, now dispersed along a track according to their molecular weight, are denatured and transferred to a nylon membrane. The scientist determines a particular VNTR sequence to be studied and adds the probe of conjugate base sequence to the nylon membrane. Said probe will bind only to the appropriate VNTR, and no other. Because the probe is radioactively labelled, the position of the VNTR along the track can be identified by the location of the radioactivity. Typically, this is done by placing a

photographic film on top of the nylon membrane; the developed film is termed an autorad. A given probe can be washed off the membrane, and a different probe, conjugate to a different VNTR can be added, and the process repeated. For ease in representation, the DNA of the crime scene, the DNA of the suspect, and calibrating (bacterial) DNA are typically placed on different tracks on the same plate/nylon membrane. To see if a match exists, one merely looks to see if one has the same VNTRs at the same molecular weights for crime scene and suspect DNA. Typically, four different VNTRs might be studied.[72]

The scientific logic of DNA profiling for individuation is as follows. There is a generally accepted proposition that the DNA molecule of a given individual is unique, except for the case of identical twins. There is a generally accepted proposition that this uniqueness is manifested in variations in the sizes of VNTRs from one individual to another. There is a conceptual disagreement over the basis of size variation in VNTRs and there is a fundamental disagreement about how to convert the VNTR size information into probabilities.

2. The proper model to describe size variation of VNTRs.

Supporters of the current DNA profiling approach, including Professors Ranajit Chakraborty and Kenneth Kidd, consider VNTRs to be traditional alleles.[73] Thus, VNTRs segregate according to Mendelian principles.

Chakraborty and Kidd acknowledge certain differences between VNTRs and traditional alleles.[74] First, VNTRs have a higher mutation rate, which could affect the accuracy of identifications between related people (for example, parent/child). Second, there is more variability in a VNTR at a specific site on DNA than for a traditional allele. Thus, one might have a handful of traditional alleles for a given site on the DNA, but one can have a hundred possible VNTR alleles. Third, because of technical limits in measuring molecular weight, one must treat the

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[72] A given VNTR sequence may give rise to two bands in the autorad, one weight range inherited from the father, a different weight range from the mother. About 87% of alleles are heterozygous. See *Jakobetz*, 747 F Supp at 253.

[73] Ranajit Chakraborty and Kenneth Kidd, *The Utility of DNA Typing in Forensic Work*, 254 Science 1735 (Dec 20, 1991). An allele is one of two or more alternative forms of a gene occupying the same locus on the DNA molecule; the different alleles in Mendel's peas gave rise to the different colors.

[74] Id at 1736.

VNTR alleles as if they formed a quasicontinuous series.

In contrast, critics of the early "fingerprinting" schemes, such as Professors Richard Lewontin and Daniel Hartl, analogize variations in VNTR sizes to a quasicontinuous array of phenotypes, such as height or weight.[75] In this view, the fundamental identity of VNTRs, rather than technical limitations, forces the quasicontinuous treatment of molecular weight. Given that the molecular weight of a VNTR fragment can be measured only with a standard deviation of ± 0.6% of the mean molecular weight, there is a potential that people with VNTRs of different sizes would be experimentally indistinguishable. Sample calculations illustrate the problem. Consider a 2 X 2 grid, in which bp designates base pair, kb designates kilobase (that is, 1000 rungs on the DNA ladder):

	fragment wgt = 2kb	fragment wgt = 10 kb
9 bp in core	0.6% = 12 bp = 1.3 core	0.6% = 60 bp = 6.7 core
	1.2% = 24 bp = 2.6 core	1.2% = 120 bp = 13.3 core
	1.8% = 36 bp = 3.9 core	1.8% = 180 bp = 20.0 core
30 bp in core	0.6% = 12 bp = 0.4 core	0.6% = 60 bp = 2.0 core
	1.2% = 24 bp = 0.8 core	.2% = 120 bp = 4.0 core
	1.8% = 36 bp = 1.2 core	1.8% = 180 bp = 6.0 core

For a VNTR core unit of 30 base pairs, an uncertainty of 0.6% of molecular weight (=1 standard deviation) or of 1.2% of molecular weight (=2 standard deviations) does not produce an uncertainty greater than 1 core unit. Thus, the experimental uncertainty is small enough to allow the determination of the number of repeated cores to within one core unit, and individuals who have a different number of core units at the DNA locus can be distinguished. However, for the other cases, the uncertainty is greater than one core unit, and individuals who have a different number of core units at the DNA locus cannot be distinguished. Thus, with respect to the issue of false positives, there are situations in which one could match within the limits of experimental error, but not match within the context of the underlying theory. Typically, the private labs have declared a match between crime scene and suspect DNA if the two are within three standard

[75] Lewontin and Hartl, 254 Science at 1746 (cited in note 60).

deviations (1.8% of molecular weight);[76] the FBI lab uses a binning approach.[77]

The experimental issues of declaring a match are non-trivial. The California Association of Crime Laboratory Directors (CACLD) submits test samples to the private DNA testing laboratories, Lifecodes and Cellmark.[78] In a group of 50 samples sent in 1987, Cellmark had one false positive, for an error level of 2%. In a group of 50 samples sent in 1988, Cellmark gain had one false positive.[79] In the 1988 samples, Lifecodes twice failed to recognize mixtures; they reported samples as arising from one person, when in fact two were represented in the sample.[80]

How comfortable one should be with a test of 98% accuracy depends critically on who is being tested. First, consider the mathematics of a test which is 98% reliable as applied to a population of 10,000 which is composed of 7,000 guilty people and 3,000 innocent people. Of the guilty, 6,860 guilty people will be correctly identified and 140 people will be false negatives. Of the innocent, 2,940 innocent people will be correctly identified, and 60 innocent people will be false positives. If you test positive, the probability of your being incorrectly identified is 60/6860, or only 0.9%. However, if the 98% reliable test is applied to a population of 10,000 which is composed of only 200 guilty people and 9,800 innocent people, the situation is different. Of the guilty, 196

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[76] A separate issue is the relationship between match criteria used in the matching component of DNA profiling and match criteria used in the probabilistic component of DNA profiling. Lifecodes used a window of ± 3 standard deviations for the first component but used a window of only ± (2/3) of a standard deviation for the second component. Eric Lander analogized this process to catching butterflies with a 10 foot wide net, but then attempting to prove the difficulty of the feat by showing how hard it is to catch butterflies with a six inch wide net. Eric S. Lander, *DNA Fingerprinting on Trial*, 339 Nature 501, 504 (1989).

[77] *United States v Yee*, 134 FRD 161, 172 (N D Ohio 1991) (Magistrate's Report and Recommendation adopted by the Court); *Yee* was affirmed under the *Daubert* standard in *United States v Bonds, Verdi, and Yee*, 1993 US App LEXIS 32574. Because VNTRs are numerous and sometimes close together, it is at times difficult to tell where the bands from one VNTR stop and those belonging to another start. VNTR frequencies can be estimated by creating bins (intervals) that have arbitrary boundary points, usually defined with reference to bacterial DNA fragments. All measured bands falling within the bin are identified as the same VNTR.

[78] William C. Thompson and Simon Ford, *The Meaning of a Match: Sources of Ambiguity in the Interpretation of DNA Prints* in Farley and Harrington, eds, *Forensic DNA Technology*, at 142-44 (cited in note 67).

[79] Id. See also Falk, Newsday at 7 (cited in note 65): "If the samples had been from actual criminal cases, Cellmark could have linked two innocent people to murders or rapes. And juries would have been told the chance of error was less than one in a million."

[80] Id. In contrast, the FBI laboratory is tested on a regular basis and has never been found to have made a false match. *State v Harris*, 1992 Tenn Crim App LEXIS 492, *12.

guilty people will be correctly identified, and there will be 4 false negatives. Of the innocent, 9604 innocent people will be correctly identified, and there will be 196 false positives. If you test positive, the probability of your being incorrectly identified is 196/392, or 50%.

C. Identification of Issues in the Probability Component of Profiling

Consider a hypothetical situation in which DNA profiling might be used. In the investigation of a rape, a comparison between the DNA of the semen removed from the victim and the DNA of the suspect's blood shows a match for all six of the VNTRs studied. The court needs to know the probability of a match between the DNA semen and any given person. The analytical situation presented is analogous to that found in *People v Collins*.[81]

Simplifying somewhat, in *Collins*, an eyewitness to a robbery testified to the existence of six facts: 1. the robbers had a yellow car, 2. the man had a mustache, 3. the girl had a ponytail, 4. the girl had blond hair, 5. the man had a beard, and 6. the robbers were interracial. The prosecution brought in a mathematician who assigned probabilities for the existence of each factor, multiplied them together, and concluded that the probability that any given couple would exhibit all six factors was 1 in 12 million. There was an issue of how the probability of each factor could be measured. Furthermore, there was an issue of statistical independence, for by multiplying each probability, the expert was implicitly assuming that the presence of each factor was independent of the presence, or absence, of the other factors.[82] In fact, one could argue that a man with a mustache is more likely to have a beard than a man without a mustache, and the probabilities are not independent.

In the rape hypothetical, the match of the six VNTRs is like the match of the six facts in *Collins*, and the problems are to assign correctly the individual probabilities and to determine whether or not statistical independence exists. Or, as Richard Lewontin and Daniel Hartl phrased the questions,

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[81] *People v Collins*, 68 Cal 2d 319, 66 Cal Rptr 497, 438 P2d 33 (Cal 1968); 36 ALR 3d 1176.

[82] Id at 37 n 10.

1. From which reference population does one get the probabilities for the individual bands?
2. After determining the answer to 1, how does one combine the data of the probabilities for individual bands into a probability for the occurrence of all bands?[83]

Of the first question, Lewontin and Hartl illustrated possible complexities by comparing the probabilities of occurrence of six specific blood group genes between Polish and Italian populations. The six genes were far more prevalent in the Polish population, with a probability of 1 in 14,000 of a match to all six. For the Italian population, the probability was 1 in 3.3 million. Applying these numbers to the above rape hypo, with all other factors equal, a match to an Italian suspect would be 240 times "more incriminating" than a match to a Polish suspect. Consider another variation. Following a match of several VNTRs pursuant to a rape case, the FBI declares the probability of match between the crime scene DNA and any given person to be 150 million to 1. However, the suspect's brother may be implicated, and the probability that the brother's DNA may match is between 128 and 256 to 1.[84]

Of the second question, Lewontin and Hartl pointed out that the VNTRs may be in a state of linkage disequilibrium, in which case the probabilities of individual VNTRs may not be independent of the probabilities of other VNTRs. Lewontin and Hartl made three recommendations:

1. Don't multiply.
2. Use ethnic ceilings.
3. Expand the current databases.[85]

In the final report of the National Research Council of the National Academy of Sciences, which issued about four months after the Lewontin/Hartl paper was published, suggestions 2 and 3 were incorporated.[86] The multiplication rule is combined with what is called the "ceiling principle."

In the near future, the report recommends that the probability for any VNTR be the highest frequency found for any of the three major population groups in the United States (Caucasian,

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[83] Lewontin and Hartl, 254 Science at 1746 (cited in note 60).

[84] Bruce Rensberger, *FBI Chief Backs DNA 'Fingerprinting'*, Wash Post A17 (Dec 25, 1991).

[85] Lewontin and Hartl, 254 Science at 1749 (cited in note 60).

[86] Roberts, 256 Science at 301 (cited in note 18).

African-American, Hispanic), or 10%, whichever is higher. In the rape hypothetical with a match of six VNTRs, this NAS rule would mean that the probability of a match to anyone could be no higher than one in a million. If a given VNTR is found to be more probable than one in ten in any given population group, the cumulative probability would go proportionately below one in a million.

The NRC report recommended the analysis of 100 individuals in each of 15 to 20 genetically homogeneous populations (for example, English, German, Russian, Vietnamese, Puerto Rican). With this database created, the NAS rule would be that the probability for any VNTR would be the highest frequency found in any of the populations, or 5%, which ever is higher. In the rape hypothetical with a match of six VNTRs, this NAS rule would mean that the probability of a match to anyone could be no higher than one in 64 million.

Initially, both sides of the theoretical debate seemed to be comfortable with this compromise.[87] There was far less controversy over the adoption of recommendations for mandatory accreditation of DNA typing labs and mandatory proficiency tests. Ironically, the largest potential source of error lies in poor laboratory practice, an issue not covered in the original *Frye* standard, rather than in the validity of the underlying scientific method, an issue covered by *Frye*.

D. Dealing with Serial Multi-component Scientific Method

In DNA profiling, one first performs a matching experiment in the laboratory. Only if there is evidence of a match is the probabilistic assessment made. In a serial, multi-step method, error inherent in earlier steps propagates to later steps. If the frequency of laboratory error with respect to false positives is 1 in every 50 at the first step, it is meaningless to discuss an overall frequency of error of 1 in a million or 1 in a billion. The overall frequency of error is still at least 1 in every 50.

To see this more clearly, let us assume, contrary to fact, the entire DNA molecule is analyzed, and the probability of error in the second step is zero. The overall probability of error is not

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[87] But, see Devlin, Risch and Roeder, 259 Science at 748 nn 6-14 (cited in note 19). The authors state: "In conclusion, we have serious concerns that the erroneous assumptions and conclusions in the NRC report are receiving undue weight in judiciary decisions. It would be unfortunate if these errors were to influence decisions of the admissibility of a very powerful forensic tool." Id at 837.

zero, because non-zero error still resides in the first step. In this idealized world, such error might arise from stupid human mistakes, such as misidentified samples, but it is nevertheless non-zero error, which should be quantified and presented.

In the real world, unfortunate laboratory errors do occur, not only in DNA profiling[88] but also in methods related to DNA profiling.[89] Furthermore, as noted above, the currently available experimental methods of measuring molecular weight of fragments are incommensurate with the theory; since a three standard deviation window is used, fragments with different numbers of base pairs can be considered to be equal.[90] This does not suggest that DNA profiling should not be admissible; merely, the proponent should adequately account for the existence of such mistakes in a discussion of the overall frequency of error.

This discussion should be from an ex ante perspective, perhaps based on the results of the mandatory proficiency testing suggested by the NRC report. The objective is to establish the frequency of error of the laboratory in attaining the result of the generally accepted technique.

III. *FRYE* AND WHY

In the five year interval between the first appellate DNA case[91] and the present, no court has held DNA matching evidence inadmissible because the theory or underlying technique were either not generally accepted or not reliable. Specific test results were held inadmissible because of faulty lab practice in *Castro*,[92] *Ex Parte Perry*,[93] and *State v Woodall*[94] and there was a question of the extension to forensic science in *Two*

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[88] Lander, 339 Nature at 501 (cited in note 76).

[89] *Prater v State*, 307 Ark 120, 820 SW2d 429, 432 (Ark 1991).

[90] I am not suggesting that DNA profiling necessarily leads to inaccurate results because of this. However, there is squarely a *Frye* prong two issue because the technique is insufficient to show that there are the same number of base pairs in the fragments of suspect and crime scene VNTRs, as is required by the theory. The statement "all individuals have unique DNA" implies that a match requires the suspect and crime scene VNTRs to have exactly the same number base pairs in VNTRs, not just a similar number. The technique treats anything within ± 1.8% (or ± 2.5% for the FBI) as being the same. Thus, the proponents of profiling in *Maine v McLeod* declared a match to exist when the VNTR bands between suspect and crime scene visibly did not match up. Norman, 246 Science 1556 (cited in note 60). See also *Ex parte Perry*, 586 So2d 242, 251 (Ala 1991).

[91] *Andrews v State*, 533 So2d 841 (Fla Dist Ct App 1988).

[92] *Castro*, 545 NYS2d at 985.

[93] *Ex parte Perry*, 586 So2d 242 (Ala 1991).

[94] *State v Woodall*, 182 W Va 15, 385 SE2d 253 (WV 1989).

Bulls.[95] In contrast, the probabilistic component of DNA profiling has been found inadmissible both before the NRC report (*Schwartz*,[96] *Curnin*[97], *Pennell*[98]) and after (*Cauthron*,[99] *People v Pizarro*,[100] *Porter*,[101] *Rivera v State of Wyoming*,[102] *Vandebogart*[103]) because the theory was either not generally accepted or not reliable.

The continued departure from unquestioned acceptance of the probabilistic evidence results, in part, from the NRC report which was issued in April 1992. This in turn was influenced by the now-famous December 20, 1991 issue of Science, which featured a debate between proponents and critics of the then-used probabilistic evidence. The tenor of the articles in Science in turn derived from the January 1991 decision in *United States v Yee*, which involved a full-fledged battle of the experts.

The debate is far from over,[104] but there is little doubt that DNA profiling evidence will be found admissible and that the finally agreed-upon reliability will be high. This is the correct result. The test is accurate and it is far superior to other methods of individuation. In the future, improvements in the profiling methodology may render the probabilistic debate entirely academic.

The important message of the DNA profiling debate is not about DNA profiling itself, but rather about the relationship between science and law. *Frye* places scientists and judges in their proper fields of expertise: scientists make the arguments about the technique and judges determine if criticisms have been met. During the DNA profiling debate, the scientific community considered testability, peer review or publication, error rate, and standards controlling the technique's operations before embracing DNA profiling, or at least matching evidence, in the NRC report. Under *Daubert*, this debate would be compressed into the period

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[95] *United States v Two Bulls*, 918 F2d 56 (8th Cir 1990).

[96] *State v Schwartz*, 447 NW2d 422 (Minn 1989).

[97] *Commonwealth v Curnin*, 409 Mass 218, 565 NE2d 440 (Mass 1991).

[98] *State v Pennell*, 584 A2d 513 (Del Super Ct 1989).

[99] *State v Cauthron*, 120 Wash 2d 879, 846 P2d 502 (Wash 1993).

[100] *People v Pizarro*, 10 Cal App 4th 57, 12 Cal Rptr 436 (1992).

[101] *United States v Porter*, 618 A2d 629 (DC 1992).

[102] *Rivera v State of Wyoming*, 840 P2d 933 (Wy 1992). Although the use of probabilities was held to be harmless error as to the defendant Rivera, the court noted: "We, therefore, believe the better practice in Wyoming should be to not refer to the statistical probability of duplication when introducing DNA test results."

[103] *State v Vandebogart*, 136 NH 365, 616 A2d 483 (NH 1992).

[104] Devlin, Risch, and Roeder, 259 Science at 748 (cited in note 19).

of a trial, and, in the end, it would be the trial judge, and not the relevant scientific community itself, who decides whether the technique is "scientifically valid."[105] It is reasonable to question the competence of the trial judge to make such a multi-pronged determination. In fact, the Chief Justice highlighted the difficulty of this inquiry in his dissent in *Daubert*.[106] Under *Frye*, though, if the scientific analysis is prepackaged, as in the case of the NRC report, the task of the judge is easy. However, even if it is not, the judges should be able to identify the common core of agreement in the scientific community, and the points of departure.

In the debate over DNA profiling, there were at least two key cases, *Yee* and *Castro*, which illustrate why a *Frye* type of analysis is superior to a Federal Rules of Evidence analysis for admissibility, and where *Frye* itself can be improved. Following a discussion of these cases, I will analyze specific criticisms which have been directed at the *Frye* standard.

A. *United States v Yee*

Yee was an appeal of a magistrate's decision to admit DNA profiling evidence. Nominally, the decision in *Yee* is based upon a *Frye* analysis, as modified by the Sixth Circuit decision of *United States v Green*.[107] The defendant raised three issues on appeal to the District Court:

1. The meaning of general acceptance in *Frye*,
2. The meaning of reliability,
3. The final prong of the *Green* test, which relates to Federal Rule of Evidence 403.

The third issue was considered to be premature.[108]

The issue of reliability arose because of the Sixth Circuit decision in *United States v Franks* which appeared to equate general acceptance in the scientific community with a showing that the specific principles and procedures on which expert testimony is based are reliable and sufficiently accurate.[109] The

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[105] *Daubert*, 113 S Ct at 2796.

[106] *Daubert*, 113 S Ct at 2800 (Rehnquist, concurring in part and dissenting in part).

[107] *United States v Green*, 548 F2d 1261 (6th Cir 1977).

[108] *Yee*, 134 FRD at 213 (Magistrate's Report and Recommendation accepted by the Court).

[109] Id at 167 (citing *United States v Franks*, 511 F2d 25, 33 n 12 (6th Cir 1975). Reliability is intertwined with general acceptance in the *Kelly/Frye* standard. *Pizarro*, 10

court indicated that the two standards were different:

> If in making its determination about the level of acceptance . . . [if] a court ventures into adjudicating the merits of any underlying scientific disputes, it necessarily will be required to reach conclusions about the validity of the scientific principles and reliability of the procedures and results. At that point, [the standard that evolved for determining the admissibility of novel scientific evidence] would improperly become converted into a hearing whose outcome is dependent on the court's determination of the validity and reliability of the scientific method employed by the proponent. The effect of adjudication of the merits of the scientific dispute, is, therefore, unavoidably to abrogate the . . . standard and substitute in its place [a] reliability standard.[110]

The *Yee* court noted that the key issue was the opinion of the scientific community as to the acceptability of the explanatory theory, not the opinion of the court as to the theory's reliability.[111] In assessing the "scientific validity" intrinsic within the notion of "evidentiary reliability,"[112] this of course is the crux of the distinction between *Frye* and Federal Rules based standards.

As to the general acceptance issue, the magistrate had done an excellent job of gathering all of the experts in the DNA profiling area. The problem was what to do in a situation in which credible proponents disagree with credible critics. The *Yee* court rejected the counting of scientific noses,[113] as other courts have also rejected consensus approaches to satisfy general acceptance.[114] For the *Yee* court, the crucial consideration in favor of admissibility under general acceptance was that experts other than performers of the test (here, the FBI) had testified in favor of the test.[115] Of one of these experts, the *Yee* court noted:

Cal App 4th at 76-77, 88; *Barney*, 8 Cal App 4th at 810.

[110] Id at 197, as quoted in Note, *DNA Profiling Evidence: the Need for a Uniform and Workable Evidentiary Standard of Admissibility*, 26 Val U L Rev 595, 628 (1992).

[111] *Yee*, 134 FRD at 167.

[112] *Daubert*, 113 S Ct at 2795 n 9.

[113] *Yee*, 134 FRD at 165.

[114] *State v Pennington*, 327 NC 89, 393 SE2d 847, 853 (NC 1990) (The court focussed on reliability of the scientific method rather than its popularity within the scientific community); *Caldwell v State*, 260 Ga 278, 393 SE2d 436 (Ga 1990). For an account of a situation in which scientific consensus was wrong for 64 years, see J.M. McBride, *Hexaphenylethane Riddle*, 30 Tetrahedron 2009 (1974).

[115] *Yee*, 134 FRD at 165.

> Dr. Caskey no doubt hopes that the ruling in this case will favor the FBI, as it will provide a judicial imprimatur to his own program. But from his perspective, the legal contest is less important, in terms not only of his professional standing, but, as well, for the long-term welfare of his forensic laboratory. Regardless of how his views are received in this or any other court, it is clear that Dr. Caskey has more to lose if his decisions are judged to have been erroneous from a scientific perspective, and if his confidence in the quality of the procedures is proven to have been mistaken. To some extent, therefore, Dr. Caskey has staked his professional reputation on the accuracy of his judgment regarding the scientific quality of the FBI's procedures.[116]

In short, the court looked to the reputational stake of the proponent's experts instead of trying to determine a common ground among all the scientists.[117]

Once the *Yee* court utilized reputational stake of individuals as a proxy for general acceptance, it had departed completely from *Frye*. Although *Yee* was correct to reject judicial determination of reliability, it should not have substituted scientific self-interest for a scientific determination of validity. First, reputational stake has nothing to do with scientific validity. It will motivate a proponent of disreputable science as much as it will motivate a seeker of truth. Second, how one person is perceived in the scientific community is distinct from how a scientific theory is perceived in the community. While there may be a correlation in the acceptance of theories with the acceptance of individual scientists, few scientists have in-depth, critical knowledge of theories outside of their own narrow specialization. If they hear of a controversy in the field of DNA profiling, most scientists will not be quick to judge rightness or wrongness, and they will be even less predisposed to heap scorn on the individual scientist. The responses of scientists to the controversy of the December 20, 1991 issue of Science are typical: scientists were quick to see the point of view of each side.[118] Thus, reputational

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[116] Id at 203 (Court adopts Magistrate's Report and Recommendation).

[117] Furthermore, the reputational stake argument would seem to favor the critics, not the proponents. Unlike the proponents, the critics had absolutely nothing to gain, but still had the same downside risk if proven wrong.

[118] Leslie Roberts, *Fight Erupts Over DNA Fingerprinting*, 254 Science 1721 (1991): "'They are all smart people,' says James Crow, a human geneticist at the University of Wisconsin. To Crow and others, like Francisco Ayala, a population geneticist at the

stake, especially among established scientists, is not a proxy for general acceptance. Under *Frye*, general acceptance is in fact itself a proxy for both reliability and validity of the theory and method.

In *Yee*, the expert critics of the probability component of DNA profiling raised important issues. The *Yee* court simply ignored them. The proper response under *Frye* would have been to establish common ground, to determine that which is generally accepted among the experts. Extensions from that common ground could have been made if objectively justifiable. For instance, if the proponents could have made a numerical case that conservatism about VNTR probabilities always would compensate for uncertainties about linkage equilibrium, the result might have been more palatable. In effect, the *Yee* court ignored the arguments of the critics.[119]

In contrast,[120] the National Academy of Sciences indeed sought and achieved a compromise in the NRC report that represented the common ground among the scientists. This approach should be a model for the general acceptance standard of *Frye*. General acceptance does not involve a counting of scientific noses. Rather, it represents the delineation of a defensible scientific position. The position is not fixed in time; further experiments can enlarge, or shrink, the common ground. But the burden must

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University of California, Irvine, the debate is not about right and wrong but about different standards of proof, with the purists on one side demanding scientific accuracy and the technologists on the other side saying approximations are good enough."

[119] *Yee*, 134 FRD at 183 (Court adopts Magistrate's Report and Recommendation). Defense expert Eric Lander: "It is a good idea to be conservative about those individual frequencies, and I support the fact that the FBI intends to be conservative about the individual frequencies, but they are apples and oranges. One pertains to whether there's a correlation. The other pertains to your estimate of individual facts, and you can't, you know, penalize yourself on "A" to make up for a problem on "B"; it's apples and oranges. . . . [The court paraphrased Lander:] Being cautious and careful in the use of the bin approach may have referred to calculating a frequency given a database by adding up everything within it but not to serve as a finesse to a different question. Thus, even though the end result might be right, that would not make the method by which that result was attained scientifically acceptable: the fact that . . . it might turn out to be right doesn't mean that it's got valid scientific method underlying it." Id.

[120] Although I do not think that *Yee* properly applied the *Frye* general acceptance standard, the mere fact that *Yee* used a *Frye* standard yielded a significantly different result than would have been obtained under Federal Rules. The scientists involved in *Yee* understood how *Frye* worked, and proceeded to publish in refereed scientific journals. This promoted discussion, and facilitated the generation of some legal changes. In a world based on the Federal Rules, there is no incentive for such analysis in the case of a technique such as DNA profiling, for which there is no doubt of probative value and little doubt of legal reliability.

on the proponent to prove to his peers that he can do what he claims.

B. *People v Castro*

The problem in *People v Castro*[121] was not with the theory or technique of DNA profiling. The individual testing laboratory was sloppy in executing the technique. The *Castro* court added a third part to the admissibility inquiry to deal with this laboratory error. The third part requires asking whether the testing laboratory performed the accepted scientific technique. This ex post inquiry into what a testing lab did in the specific case should not be a question of admissibility. Acceptance of actual results in specific cases is an issue of weight, not admissibility.[122]

To remain consistent with *Frye*, the more appropriate third part is whether the methods actually employed are routinely capable of giving the result of the generally accepted technique.[123] The traditional second part of *Frye* asks merely whether there are techniques that currently exist that are capable of producing reliable results; it does not ask whether a given laboratory is capable of performing them.

The proposed third part is simply an ex ante inquiry into whether a given testing lab uses a specific procedure which complies with the generally accepted theory and technique. It is an appropriate *Frye* inquiry. Just because a generally accepted theory and technique exist does not imply that any testing lab is capable of competently executing the technique. If there is no demonstration of proficiency, admissibility should be denied. Conversely, one does not want prolonged admissibility hearings to accompany every DNA profiling case. Presentation of the results of mandatory proficiency testing would be sufficient to pass this third prong.[124] If there are problems with the particular re-

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[121] *Castro*, 545 NYS2d at 985.

[122] This has been a point of discussion in recent DNA profiling cases in California. *Barney*, 8 Cal App 4th at 823.

[123] This proposed third part to *Frye* is consistent with the third part of *Frye* articulated in *Kansas v Witte*, 836 P2d 1110 (Kan 1992): "(3) the officer administering the test has been trained to follow the procedures established by the scientists to test the phenomenon. . . ."

[124] Although this approach is not equivalent to the third prong of *Kelly/Frye*, the final result is similar. "All that is necessary in the limited third-prong hearing is a foundational showing that correct scientific procedures were used." *Barney*, 8 Cal App 4th at 825.

sults in a given case, questions must go to the weight and not admissibility.

C. A Response to the Criticisms of *Frye*

A recent commentator listed five criticisms of the *Frye* test.[125] This part proposes solutions to the criticisms, so as to make *Frye* a standard for novel scientific evidence at the state court level.

1. What is general acceptance?

A generally accepted concept, at a minimum, is one which is agreed upon by both proponents and critics. Proponents may advance beyond this common core by an experimental or theoretical showing of accuracy in a peer-refereed journal or substantial equivalent.[126] Such showing should constitute a rebuttable presumption, which may be defeated by later data directly negating the contention of the proponent.

General acceptance is not defined with reference to scientific consensus; it is determined by the validity of the underlying scientific technique. Validity is determined by the ability of the proponents to respond to the relevant questions of the critics. The history of DNA profiling shows that these relevant questions are identifiable.

2. What must be generally accepted?

Both theory and technique must be generally accepted. A theory without a technique for reduction to practice would not yield empirical results. A technique without a theory would not have scientific validity.

The correctness of results in a particular case is an issue of

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[125] Comment, 79 Georgetown L J at 318-20 (cited in note 21).

[126] I am in complete agreement with the *Daubert* court that publication should not be a sine qua non of admissibility and that publication does not correlate with reliability. *Daubert*, 113 S Ct at 2797. At a minimum, there must be sufficient articulation of a theory and arrangement of data such that a scientist trained in the field can analyze the theory and data for validity. Conversely, significant publication does not prove reliability, as illustrated by the story of the hexaphenylethane in McBride, 30 Tetrahedron at 2009 (cited in note 114) and the story of buckminsterfullerene in soot in Lawrence B. Ebert, *The Interrelationship of C(60), Soot and Combustion*, 31 Carbon 999 (1993).

weight, not admissibility. As the *Daubert* court noted in its Rule 702 inquiry, "[t]he focus, of course, must be solely on principles and methodology, not on the conclusions they generate."[127]

3. What is a particular field?

The concept of a "particular field" is self-defining. Any person who has made an experimental or theoretical showing of relevance to the theory or technique in question belongs to the "particular field". While a proponent can publish his work, in a peer-refereed journal or substantial equivalent, to meet his burden of demonstrating validity, such a requirement is not needed to establish "particular field." Moreover, even if the relevant field is unclear, this does not mean that criticism from an arguably different field will go unheeded. If someone in the Swiss patent office can show that DNA profiling does, or does not, work as claimed, it simply does not matter that the person is not a biochemist or a population geneticist.[128]

In the context of DNA profiling, one notes that, although this issue was raised, it was resolved without difficulty.

4. When does the *Frye* test apply?

In a jurisdiction which employs *Frye*, the test would apply to any scientific test previously unaccepted in that jurisdiction. Once the jurisdiction has accepted the scientific test, there should be little need for additional *Frye* hearings, unless significant new evidence became available. Finally, as noted in *Daubert*, "theories that are so firmly established as to have attained the status of scientific law, such as the laws of thermodynamics, properly are subject to judicial notice under FRE 201."[129]

5. The "cultural lag" problem.

At no point in the evolution of a scientific test should a criminal defendant bear the consequences of uncertainties in accuracy of that scientific test when it is reasonably foreseeable that those uncertainties will diminish. Although no test is 100% accurate,

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[127] *Daubert*, 113 S Ct at 2797.

[128] California courts address this, and the general acceptance issue, in seeking to determine whether "scientists significant either in number or expertise publicly oppose [a technique] as unreliable." *People v Wallace*, 14 Cal App 4th 651, 17 Cal Rptr 2d 721 (1993), quoting *People v Brown*, 40 Cal 3d 512, 533, 220 Cal Rptr 637 (1985).

[129] *Daubert*, 113 S Ct at 2796.

and there will always be false positives, error frequencies should be set conservatively in transitional periods during which information is incomplete.

CONCLUSION

For novel science, admissibility standards in which scientists assess questions of scientific validity are preferable to those in which judges perform the same task. The *Frye* standard is preferable to various standards based on the Federal Rules of Evidence. By incorporating the opinions of scientists, the legal system ensures a restoring force by which judicial opinions are pointed in the direction of the current common core of scientific knowledge. The history of the admissibility of DNA profiling evidence illustrates the significant role that scientists can play in resolving issues; the most recent manifestation of this can be seen in the use of state courts of the NRC's report on DNA Technology in Forensic Science. Although *Frye* includes inquiries into the general acceptance of theory and technique, it may not address all possible questions of reliability. However, a third prong for admissibility of novel scientific evidence could determine whether the methods actually employed by a testing laboratory are routinely capable of giving the result of the generally accepted technique.