DNA EVIDENCE IN CRIMINAL TRIALS: MODIFYING THE LAW'S APPROACH TO PROTECT THE ACCUSED FROM PREJUDICIAL GENETIC EVIDENCE

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"Justice is truth in action."

Benjamin Disraeli, Earl of Beaconsfield, 1851[1]

They found the body of little twelve-year-old Cassie Holden in the bushes of a golf course in Kitsap County, Washington, in 1988.[2] When Jonathon Gentry was arrested for the crime and subsequently brought to trial, the crucial evidence tying him to the scene of the crime was the victim's blood spattered on his shoes. Gentry had unwittingly carried this blood containing the victim's genetic material with him until he was arrested. The investigating authorities used the genetic material found in Cassie Holden's blood, called DNA, to prove their case against Gentry, who now sits on death row for her murder.[3]

The chemical structure of deoxyribonucleic acid (DNA) contains the design for every living organism. It is this chemical structure that gives each individual his or her own "unique genetic signature."[4] Each DNA signature is so unique that no two individuals, except identical twins, have the same signature.[5] Police science puts the identification power of this valuable biological tool to work solving crimes. Because DNA typing expresses the results with more certainty than any of the other traditional forensic methods,[6]

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* The author would like to express appreciation to Ms. Josephine Sotelo, Attorney at Law, Tucson, Arizona, Mr. Vincent Q. Kirby, of the Maricopa County Attorney's Office, Phoenix, Arizona, and Dr. Thomas Lindell of the University of Arizona Department of Biology for their invaluable insights and assistance in the researching and drafting of this paper. Relevant Trial Court Opinions and Orders cited herein are on file with the *Arizona Law Review.*

1. JOHN BARTLETT, BARTLETT'S FAMILIAR QUOTATIONS 612 (1968).
2. *DNA Fingerprinting: Law's New Frontier*, THE SEATTLE TIMES, March 2, 1992, at E1.
3. *Id.*
4. LORNE T. KIRBY, DNA FINGERPRINTING: AN INTRODUCTION xv (1990).
5. William F. Thompson & Simon Ford, *DNA Typing: Acceptance and Weight of the New Genetic Identification Tests*, 75 VA. L. REV. 45, 61–62 (1989).
6. ANDRES MOENSSENS ET AL., SCIENTIFIC EVIDENCE IN CRIMINAL CASES 355 (3d ed. 1986). The more traditional methods of forensic identification include but are not limited to blood-marker typing, and secretor status typing. *See generally,* Thompson & Ford, *supra* note 5.

crime laboratories throughout the country have enthusiastically embraced DNA typing as a forensic tool, and its use appears to be on the rise.[7]

DNA typing, first proposed in 1980,[8] is popular within the forensic community because of its virtual certainty of identification and the abundance of DNA in all areas of the body.[9] Although the physical evidence left at crime scenes may vary widely, the DNA comprising the physical evidence does not.[10] Furthermore, DNA is remarkably stable in the individual throughout time; as the individual ages, the DNA structure will remain the same.[11]

DNA typing's potent evidentiary power and its unchanging form and function give it widespread forensic appeal. Increasing crime rates create the demand.[12] Some commentators believe that widespread use of DNA testing would streamline the operation of the criminal justice system[13] and would increase the number of victims who are willing to come forward and report rapes.[14] The greatest impact, however, may be the utilization of this method to form a national data base containing the DNA profiles of sex offenders and other criminals.[15] DNA typing is likely to leave its mark on other areas of the law as well.[16] The legislatures of some states, impressed with its potential

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7. U.S. CONGRESS, OFFICE OF TECHNOLOGY ASSESSMENT, GENETIC WITNESS: FORENSIC USES OF DNA TESTS 22 (1990) [hereinafter GENETIC WITNESS]. Over three-quarters of the 221 crime laboratories surveyed by the OTA responded positively to DNA testing, stating that is was "important to their mission." *Id.* at 22. When the survey was conducted in 1989, almost half of the responding crime laboratories indicated that they were contracting with outside laboratories for DNA analysis at that time. Moreover, 46% of the laboratories indicated they had plans to implement their own onsite testing programs within the next two years. *Id.*

8. KIRBY, *supra* note 4, at 2. Although the foundations of DNA typing were first observed in 1980, the technique was not perfected until 1985 when researcher Alec Jeffreys published his paper on the subject. *See* Alec Jeffreys et al., *Hypervariable 'Minisatellite' Regions in Human DNA*, 314 NATURE 67 (1985).

9. KIRBY, *supra* note 4, at 8. DNA is present in all nucleated cells. Generally, this includes all cells in the human body except red blood cells. DNA may be found in fresh tissue samples, including whole blood, epithelial (mucous membrane) cells, hair follicles, blood stains, semen stains, tooth pulp, and bone marrow. *Id.* at 51.

10. *Id.* at 2.

11. Thompson & Ford, *supra* note 5, at 61–62.

12. In 1988, 92,486 forcible rapes and 20,675 murders and non-negligent manslaughter cases were reported to U.S. authorities. GENETIC WITNESS, *supra* note 7, at 17. The actual number of rapes that occurred is probably higher because not all rapes are reported. *Id.*

13. Kenneth Melson, *Legal and Ethical Considerations, in* KIRBY, *supra* note 4, at 189, 190. DNA dramatically increases the weight of the prosecution's case when it is used against the defendant accused of rape; most defendants confronted with DNA test results that inculpate them have pled guilty. *Id.*

14. Because defendants against which DNA evidence is introduced are more likely to plead out, these authorities contend that rape victims will be more willing to report the crime because of the lessened possibility of undergoing the trauma of being a victim-witness at a rape trial. *Id.* at 191.

15. California, Colorado, Nevada, Virginia and Washington are drafting or have already enacted legislation that allows for the collection of blood from sex offenders to be used to develop a DNA profile data base. KIRBY, *supra* note 4, at 126. The FBI is in the process of developing uniform standards for DNA typing that will assist in the establishment of a nationwide DNA data bank. Melson, *supra* note 13, at 200.

16. DNA profiling has a wide variety of applications beyond human forensic science; it can be readily used in diagnostic medicine, family relationship analysis, animal and plant science, and in the detection and prosecution of wildlife poaching. *See* KIRBY, *supra* note 4, at 4–5.

value to effective law enforcement, have passed laws loosening the admissibility requirements of this sensitive evidence.[17] Thus, the role of DNA typing in the criminal justice process seems limited only "by the circumspection of the criminal mind."[18]

Although DNA typing may be "the most important advance in forensic science since the advent of fingerprinting,"[19] some observers question the reliability of this type of evidence. Critics of the method complain that some DNA-related tradenames are misleading because they imply certainty of identification.[20] Moreover, others argue that the remarkably short implementation period—beginning with the introduction of the method in a research setting in 1985 and ending with the first criminal case that was granted appellate review in 1988[21]—is an insufficient time in which to study the full effects of transferring DNA profiling and analysis from the research environment to the forensic workbench.[22]

Two separate admissibility standards govern the admission of novel scientific evidence—the *Frye* standard[23] and the relevancy standard.[24] This Note examines these two standards, and in particular focuses on each standard's role in rejecting DNA typing evidence that has unsound analytical underpinnings or inadequate quality assurance procedures.[25] This Note argues

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17. GENETIC WITNESS, *supra* note 7, at 14. *See, e.g.*, LA. REV. STAT. ANN. tit. 15 § 441.1 (West 1992) ("Evidence of [DNA] profiles, genetic markers of the blood ... offered to establish the identify of the offender of any crime is relevant as proof in conformity with the Lousiana Code of Evidence."); MD. CODE ANN. [CRIM. LAW] §10–915 (1992) ("In any criminal proceeding, the evidence of a DNA profile is admissible to prove or disprove the identify of any person."); MINN. STAT. ANN. §§ 634.25, 634.26 (West Supp. 1992) ("[T]he result[s] of DNA analysis ... are admissible in evidence without antecedent expert testimony that DNA analysis provides a trustworthy and reliable method ...."). *See also* NEV. REV. STAT. § 56.020 (Supp. 1991). Some of these statutes are vaguely worded and were intended only to cover traditional RFLP analysis, the only method in existence at the time of drafting. Some observers call for a narrow reading of these statutes, so that new, untested variations of DNA typing are not improperly admitted at trial. NATIONAL RESEARCH COUNCIL, NATIONAL ACADEMY OF SCIENCES, DNA TECHNOLOGY IN FORENSIC SCIENCE 52 (1992) [hereinafter NATIONAL RESEARCH COUNCIL].

18. Melson, *supra* note 13, at 190.

19. United States v. Jakobetz, 747 F. Supp. 250, 258 (D. Vt. 1990), *cert. denied*, 113 S. Ct. 104 (1992).

20. The DNA typing methodology was first commercially offered by Lifecodes and Cellmark, who confidently coined the terms "fingerprint" and "print" to describe their services. Lifecodes uses a procedure they call the "DNA Print," while Cellmark Diagnostics uses a procedure dubbed "DNA Fingerprinting." Thompson & Ford, *supra* note 5, at 48–49.

21. Andrews v. State, 533 So. 2d 841 (Fla. Ct. App. 1988) (DNA evidence admissible under relevancy standard).

22. People v. Castro, 545 N.Y.S.2d 985, 990 (Sup. Ct. 1989). ("It is the transfer of this technology to DNA forensic identification that has generated much of the dispute.") The National Academy of Sciences recommends that "[a]ny new DNA typing method (or substantial variation of an existing method) must be rigorously characterized in both research and forensic settings to determine the circumstances under which it will yield reliable results." NATIONAL RESEARCH COUNCIL, *supra* note 17, at 72. The problems associated with contamination and degradation in forensic samples are discussed *infra* notes 40–45 and accompanying text.

23. *See* Frye v. United States, 293 F. 1013 (D.C. Cir. 1923), and *infra* notes 130–206 and accompanying text.

24. *See* FED. R. EVID. 401, 402, 403, and 702.

25. The DNA profiling analysis procedure is very long and involved, and any error that occurs at any point in the chain is sufficient to compromise the validity of the entire test. Thompson & Ford, *supra* note 5, at 65. A chain is only as strong as its weakest link, and

that these two governing standards of admissibility do not allow the criminal defendant the ability to defend adequately against potentially prejudicial and unreliable scientific evidence.

Part I of this Note focuses on the scientific aspects of DNA typing, both in theory and in practice. Part II examines the two legal standards—*Frye* and relevancy—that govern the admissibility of novel scientific evidence, and the shortcomings of each standard. This Note analyzes several of the DNA cases that utilize these models and then compares these cases to Arizona trial courts' treatment of this evidence.[26] Part III discusses the adversary and the jury systems and demonstrates that the criminal defendant is unable to defend against faulty DNA evidence once it reaches the jury. Part IV argues for heightened scrutiny at the pre-trial level, so that courts admit DNA evidence only after determining that the results are reliable and that the testing procedures have been properly performed. This Note argues that the judge should determine most questions regarding the technique as a matter of law at pre-trial proceedings, instead of allowing the trier of fact to weigh the evidence during the trial.

I. OVERVIEW OF DNA TYPING METHODOLOGY

DNA provides the chemical blueprint for each living organism from the smallest bacteria to the largest mammal.[27] The DNA molecule is a very long, double stranded, helical molecule that resembles a "twisted ladder."[28] Each strand of the "double-helix" is complementary to the other strand.[29] The "rungs" that hold the double-helix together are critical to forensic analysis; each rung is composed of a pair of molecules called organic bases—one at each end of the rung—which bind to each other and are known as "base pairs."[30] There are only four of these organic bases, and each will bind with

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therefore this Note will examine the reliability and general acceptance of DNA typing as it applies to each of the four parts of the process.

26. As of the writing of this Note, no DNA typing case has been decided at the appellate level in Arizona. DNA has been considered in the trial courts, although no consensus regarding the technique is apparent. *See, e.g.*, State v. Hummert, No. CR89-03684 (Super. Ct. Maricopa County, Ariz. 1991) (admitting in part denying in part); State v. Despain, No. 15589 (Super. Ct. Yuma County, Ariz. 1991) (barring admission of whole result); State v. Bible, No. 14105 (Super. Ct. Coconino County, Ariz. 1989) (admitting whole result with no opinion). This Note emphasizes trial court opinions because they contain more complete summaries of the evidence and the issues and provide a greater insight into the rationale of the judges who try these cases every day. While appellate opinions have precedential value, appellate courts are unlikely to review a case where the DNA typing has been initially rejected by the trial judge, and will review all others only for abuse of discretion. *See, e.g.*, Andrews v. State, 533 So. 2d 841 (Fla. Ct. App. 1988).

27. All nucleated cells contain DNA; DNA provides the genetic code for these cells, and is housed in the nucleus. *See* KIRBY, *supra* note 4, at 8.

28. United States v. Jakobetz, 747 F. Supp. 250, 251 (D. Vt. 1990), *cert. denied*, 113 S. Ct. 104 (1992).

29. KIRBY, *supra* note 4, at 9. The strands are fastened together by weak chemical bonds known as hydrogen bonds. *Id.*

30. Each of these bases is mutually complimentary, and they bind to each other in a rigidly predictable manner. The four bases are adenine (A), guanine (G), cytosine (C), and thymine (T). These bases are mutually complimentary in that adenine will only bind with thymine, and cytosine will only bind with guanine (A=T, C=G). Each bond forms a base pair and the entire human genetic make-up (genome) consists of about three billion of these base pairs. *Id.*

only one of the other bases. Therefore, the order of the bases along one strand determines the order of the bases along the other.[31] The order of these bases along the strands determines the genetic code and enables the forensic analyst to use DNA to solve crimes.[32] Analysts are particularly interested in the gene.[33] Some genes have many versions, and are responsible for the variable traits in the population—the different eye colors, different hair colors, different nose sizes. Other genes have only one version. These genes produce the traits that remain constant in the population, such as the presence of arms, legs and teeth. Forensic applications of DNA typing focus only on those genes that have many versions. Each of these different versions manifests itself in unique individual characteristics. These different versions also allow the forensic analyst to distinguish between two individuals. The exact location of each gene on the DNA strand is called the "locus" and the current DNA typing methods derive their power by detecting the many different versions of a gene that may be present at a very specific locus or site.[34]

The two major DNA typing procedures in use are Restriction Fragment Length Polymorphism analysis (RFLP)[35] and the Polymerase Chain Reaction (PCR).[36] Each of these procedures involves four separate components:

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31. MOENSSENS ET AL., *supra* note 6, at 356. For instance, if the bases along one strand are ACTAGT, the bases along the other side would be TGATCA.

32. Discrete sections of the strands code for different purposes and functions. THOMAS GELEHRTER & FRANCIS COLLINS, PRINCIPLES OF MEDICAL GENETICS 15 (1990). Each of these discrete sections, called codons, is three bases in length and codes for a specific amino acid. *Id.* The DNA molecule, if stretched out, would measure nearly six feet in length; to accommodate this lengthy strand in a package so small as a cell, the DNA must be tightly and intricately coiled. *Id.* at 18. The highest order of this coiling is the chromosome. Each species has a characteristic number and size of chromosomes. These chromosomes come in pairs. Humans have 22 pairs of these chromosomes, along with two sex chromosomes, which have been dubbed "X" and "Y," for a total of 46 chromosomes, or 23 pairs. One of each pair of the chromosomes is inherited from the mother, and the other pair is inherited from the father. *Id.*

33. Each chromosome carries a number of genes, which are essentially smaller delineations along the genetic staircase. Thompson & Ford, *supra* note 5, at 62. It is helpful to conceptualize the chromosome as the longest discrete section of DNA, while genes are smaller discrete units, composed of codons of base pairs, base pairs being the smallest discrete unit of the whole genome. Some genes, such as the ones that code for blood types, have more than one version. Each version of a gene is called an allele. If a gene has more than one allele or version, the gene is said to be polymorphic. If the gene only has one version, it is said to be monomorphic. *Id.* Of the three billion base pairs in the human body, only one percent, or about three million, of these base pairs vary from individual to individual, and hence are polymorphic. GENETIC WITNESS, *supra* note 7, at 3.

34. KIRBY, *supra* note 4, at 8–9.

35. Quality RFLP analysis should be conducted by several individuals. Laurel Beeler & William R. Wiebe, Comment, *DNA Identification Tests and the Courts*, 63 WASH. L. REV. 903, 927 (1988). For instance, the technician who performs the extraction and preparation of the samples should not be the technician who interprets the results. Moreover, the second technician's interpretation should be reviewed by a senior scientist or the laboratory supervisor. *Id.* Additionally, another person may be called upon to conduct the actual population genetics analysis. Most forensic laboratory procedures are substantially less involved, and may be performed by a single analyst; several different analysts working in tandem on the same project requires a different approach. This Note will examine the procedures of DNA typing in four separate parts, each part roughly corresponding to the duties performed by a different analyst in the laboratory scheme.

36. Thompson & Ford, *supra* note 5, at 50. PCR is also referred to as "allele specific probe analysis." *Id.* at 64. This Note will concentrate primarily upon the RFLP procedures; therefore, PCR will not be discussed in detail herein.

extraction/preparation, interpretation, population genetics, and quality laboratory practice.

A. Restriction Fragment Length Polymorphism Analysis

RFLP analysis seeks out the distinct regions of the DNA chain that vary from individual to individual; because they vary, these regions are called polymorphic ("many forms") regions.[37] The analyst must first separate and distinguish the DNA fragments by their length and size.[38] The procedure then utilizes the polymorphic regions as landing sites for special radioactive genetic "probes"—a type of biological magnet—which attach at pre-determined locations on the genetic staircase. These "glow in the dark" probes allow examination of the overall profile.[39] The infinite array of possible fragment lengths and the fluctuating odds of possessing a particular allele at an exact location on any one of those fragment lengths combine to give DNA typing its statistical power to identify. This extraction and preparation process consists of six steps.

1. Extraction

The forensic DNA sample may arrive at the laboratory in many different forms,[40] but raw body fluids are generally the most common evidentiary submission. These fluids cannot be analyzed directly. Therefore, purified DNA must be removed from the body fluids or tissue sample prior to any identification tests. The analyst separates the mixed body fluids, and then extracts the DNA from each specimen.[41] Once the DNA is extracted and

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37. Thompson & Ford, *supra* note 5, at 62. There are two types of polymorphisms. The first type, called restriction fragment length polymorphisms, for the purposes of DNA typing, serves as the cleavage point for restriction enzymes that carve the molecule up into discrete fragments. RFLP, then, appears to be named for this process. *See infra* notes 46–47 and accompanying text. The second type of polymorphism is less common but more useful, and for the purposes of DNA typing, serves as the location for the attachment of genetic probes which highlight the specific differences between individuals. GELEHRTER & COLLINS, *supra* note 32, at 79–80. These polymorphisms, called "variable number of tandem repeats," or VNTRs, are created by the presence of short sequences of bases that are repeated several times, one after the other (e.g., TAGTAGTAGTAG). *Id.* The function of these VNTRs is not known, but they are distinguished by the fact that the number of repeated sequences is highly variable, and each hypervariable region may have a large number of different possible alleles. *Id. See also* GENETIC WITNESS, *supra* note 7, at 44. For a more detailed discussion of VNTRs and the use of genetic probes to detect them, see *infra* notes 55–62 and accompanying text.

38. *Id.*; NATIONAL RESEARCH COUNCIL, *supra* note 17, at 37.

39. KIRBY, *supra* note 4, at 104–09.

40. The submitted sample may be a semen stain sample found at the scene of a sexual assault, or a blood stain or splatter at the scene of a homicide. The actual evidence may be combined with extraneous tissues. For instance, when semen is drawn by means of a vaginal swab, the DNA from the semen may be mixed with DNA from the victim, or the sample may be contaminated by bacterial or other non-human DNA. Whatever the case, the method of extraction and purification of the DNA will be an important issue at trial, as some contaminants could create deviant results later in the procedure. Thompson & Ford, *supra* note 5, at 66.

41. During extraction, the medium containing the DNA sample is isolated and soaked in a solution which causes the cells to lyse (break open), releasing the DNA into solution. The solution is then chemically extracted, and the DNA precipitates out as a salt. KIRBY, *supra* note 4, at 55.

purified, the analyst tests the sample for quantity[42] and quality.[43] Rape cases constitute a substantial share of DNA typing submissions, yet these cases prove to be the most vexatious of all for sample quality.[44] But whatever the type of crime that produced the DNA evidence, quality and quantity tests are essential for preventing erroneous results.[45]

2. Fragmentation

Extracted DNA fragments are too long for analysis and must be divided up into discrete sections. To accomplish this task, the analyst employs a restriction enzyme, metaphorically called a "chemical scissors," which cuts the DNA only at specific sites or loci.[46] The scientific community accepts the

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42. DNA typing requires a minimum sample size. As a general rule, a stain caused by body fluids must be larger than the size of a dime in order to obtain suitable results. KIRBY, *supra* note 4, at 52. Frequently the sample is completely consumed or destroyed during the first analysis, giving the testing laboratory only "one bite of the apple." People v. Castro, 545 N.Y.S.2d 985, 993 (Sup. Ct. 1989). This situation creates difficulties for the criminal defendant who wishes to have the test performed again by an independent expert. *See infra* notes 276–84 and accompanying text.

43. Frequently, the samples are contaminated with unknown genetic material such as bacteria, plant, or animal and human secretions. GENETIC WITNESS, *supra* note 7, at 59. Forensic samples can also contain chemicals introduced at the crime scene that can interfere with the process that divides the molecule into its component parts, and disrupt the electrophoresis which is essential to sorting the fragments out by length. *Id.* The major source of contamination is bacterial DNA that cross-hybridizes, or improperly attaches to the DNA probe. This may result in false or misleading bands. Beeler & Wiebe, *supra* note 35, at 921. Foreign DNA is readily detected by using special screening probes. *Id.* at 922. Probes are defined *infra* at note 56. Forensic casework samples are usually obtained under conditions that are less than ideal. The result is that environmental contamination may create false positives, thus falsely incriminating a criminal defendant. Because of this, the National Academy of Sciences recommends that internal tests, supported by extensive empirical study, be used on every run of a forensic sample. NATIONAL RESEARCH COUNCIL, *supra* note 17, at 72.

Environmental factors that degrade DNA can also destroy the reliability of the analysis procedure. GENETIC WITNESS, *supra* note 7, at 46, 62. Tests have shown that such factors include sunshine and soil. Yet other DNA exposed to gasoline, motor oil, detergents, acids, bases, salts, and bleaches displayed no degradation. DNA present on substrates such as cotton, nylon, glass, wood, and metal also remained stable. KIRBY, *supra* note 4, at 69–70. The extent to which DNA can survive various forms of environment pressures is still unclear. Beeler & Wiebe, *supra* note 35, at 922.

44. DNA degradation is a particular problem in rape cases, because warm moist conditions are not conducive to preserving the sample. Approximately 40–50% of the samples submitted in rape cases cannot be analyzed due to excessive DNA degradation. KIRBY, *supra* note 4, at 128.

45. The possibility of obtaining a false positive result caused by deficiencies in DNA quantity or quality is negligible. Under such circumstances no result is usually reported. Under a very few circumstances, however, a false negative could occur if a DNA contaminant is present in the probe and only one of the specimens pairs. *Id.* It is the position of this Note that a false-negative is as undesirable as a false-positive. In cases where the criminal defendant wishes to use DNA typing as exculpatory evidence, a false-negative result is of little value. *See* State v. Woodall, 385 S.E.2d 253 (W. Va. 1989). Additionally, a false-negative could result in the authorities failing to apprehend the suspect of a crime.

46. For instance, a restriction enzyme known as *TaqI* will recognize the base sequence TCGA, and will cut the DNA helix only where it finds that sequence. In monomorphic regions, then, *TaqI* will produce fragment lengths that are the same from individual to individual, and such fragments are of little interest to the forensic analyst. In polymorphic regions, however, *TaqI* will produce fragment lengths that vary from individual to individual. It is important that the restriction enzyme selected seek out polymorphic restriction (cutting) sites that flank polymorphic VNTR regions of DNA. *See* GELEHRTER & COLLINS, *supra* note 32, at 78–79;

use of restriction enzymes to cleave DNA into fragments because, if the analyst carefully uses the proper amount of enzyme, the procedure is reliable.[47]

3. Gel Electrophoresis

The size of DNA fragments is the index by which the arrangement of the bands are measured. To accurately measure the DNA fragments, the analyst uses gel electrophoresis to separate the DNA fragments by length.[48] Prior to electrophoresis, the DNA samples are arranged in a series of wells or depressions along one edge of the gel plate. Questioned casework samples are run alongside known samples containing DNA fragments of predetermined length.[49] Although gel electrophoresis is a widely used technique in many areas of science, band shifting is problematic in forensic cases.[50] Some laboratories have attempted to address this concern by applying a mathematical correction factor to the shifted bands; however, the exact equation to use is controversial.[51]

KIRBY, *supra* note 4, at 94. Two other enzymes, *Hae*III and *Hin*fI, fit the criteria and work well in forensic applications. The FBI uses *Hae*III as its enzyme of choice; it has more common recognition sites and cuts the DNA into smaller fragments which provide for better resolution. *Id.* at 143–45.

47. Thompson & Ford, *supra* note 5, at 68. The proper amount of restriction enzyme in the procedure is crucial to a valid outcome. Too much restriction enzyme could result in over-cleavage of DNA and fragments that are too short for useful analysis. Too little restriction enzyme could result in under-cleavage of DNA fragments, with fragments that are too large, and move too slowly across the electrophoretic gel plate. *See infra* note 48. When all the fragments are bunched at one end of the plate the sample cannot be evaluated. Thompson & Ford, *supra* note 5, at 68.

48. The theory of gel electrophoresis relies upon the differences in rates of travel observed when different size molecules move through a uniform environment of resistance. In much the same way as smaller rocks will proceed more quickly down a running stream than will large boulders, the DNA molecule travels across the gel plate according to its size—the shorter fragments will go further. Thompson & Ford, *supra* note 5, at 69. Thus, at the conclusion of electrophoresis, the fragments will be arranged on the gel plate according to size with the smaller fragments displayed at the far end. *Id.*

49. KIRBY, *supra* note 4, at 95–96.

50. Band shifting occurs where the DNA fragments in one lane of a gel plate migrate across the gel more rapidly than identical fragments in a second lane. Band shifting has been estimated to occur in up to 30% of forensic cases. KIRBY, *supra* note 4, at 119. Band shifting may occur to such an extent that the test may be invalidated. *Id.* at 120; NATIONAL RESEARCH COUNCIL, *supra* note 17, at 60. The analyst can declare a match only when the respective bands form a straight line at a specified location. When the bands do not migrate uniformly and fail to form this line, the analyst must declare that the samples do not match, or must declare that the evidence is inconclusive. KIRBY, *supra* note 4, at 120.

A number of factors cause band shifting, such as variations in gel block concentration, inadequate supplies of buffer solution, or misapplication of the liquid stain that allows the migration and position of the bands to be inspected under ultraviolet light. *See* KIRBY, *supra* note 4, at 98, 121–25; NATIONAL RESEARCH COUNCIL, *supra* note 17, at 57. If shifting "moves" the bands beyond the relative size markers along the edge of the gel plate, it can appear to transform one type of DNA into another. There is little agreement between forensic experts about the magnitude of importance of band shifting. Thompson & Ford, *supra* note 5, at 70.

51. KIRBY, *supra* note 4, at 120. Much of the debate has centered around the inadequate peer review afforded to the use of these correction factors. *Id.* Computer software that compensates for minor inconsistences in the data is an issue that needs to be explored. Thompson & Ford, *supra* note 5, at 76.

4. Southern Transfer

After electrophoresis, the DNA banding patterns remain bound to the gel plate, which resembles a slab of firm gelatin. These gel plates are messy and difficult to work with. A process known as Southern Transfer[52] removes the DNA bound to the gel and places it on a flexible, durable nylon membrane which is better suited for continued analysis. During Southern Transfer, the DNA is "denatured," a chemical process that literally unzips the double stranded molecule at the base pair bonds, leaving two complementary single strands.[53] Southern Transfer to the nylon membrane improves the accuracy and the ease of the procedure. The DNA fragments are drawn to the nylon membrane covering the gel plate. The fragments attach to the membrane in exactly the same arrangment as they appeared on the gel after electrophoresis.[54] The membrane preserves the graphical arrangment of the DNA fragments for the next procedure.

5. Hybridization and Probing

Fragments that are located in the variable (polymorphic) regions of the genetic make-up are important to forensic DNA typing.[55] To search for these regions, analysts use radioactively tagged DNA "probes"[56] to locate and bind to DNA fragments on the membrane.[57] Once the probe binds, or is "hybridized," to its complementary fragment on the membrane, the analyst washes the membrane to remove all probe material that remains unattached.[58]

Although genetic probing is relatively easy to do, the forensic application of this technique raises two quality assurance issues. First, the accuracy of the test turns upon the number of probes used. The probability of different individuals having the same version of a gene at the same location on the DNA staircase is very low, and repeating this process and re-hybridizing with a second, third, or fourth single-locus probe greatly increases the accuracy of

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52. The technique was named for its inventor. *See* Edwin Southern, *Detection of Specific Sequences Among DNA Fragments Separated by Gel Electrophoresis*, 98 J. MOLECULAR BIOLOGY 503 (1975).

53. KIRBY, *supra* note 4, at 102. Denaturation is necessary because the probes themselves are also short strands of denatured DNA. The denaturation process exposes the landing sites for the probes to attach.

54. *See generally*, GENETIC WITNESS, *supra* note 7, at 46.

55. *See supra* note 33 and accompanying text. *See also* Thompson & Ford, *supra* note 5, at 62. A probe may be used to seek out monomorphic regions as well. Such probes are particularly useful to determine the amount of DNA degradation. *See* KIRBY, *supra* note 4, at 182.

56. A probe is a single-stranded portion of DNA that will bind only with its complementary sequence, and, for the purposes of forensic probes, these sequences are usually located in polymorphic regions. KIRBY, *supra* note 4, at 136–37. There are two types of probes. Single-locus probes seek out sections of polymorphic DNA that occur only once in the genome (genetic makeup). Thompson & Ford, *supra* note 5, at 72. Multi-locus probes, on the other hand, seek out "families" of polymorphic DNA, and hence attach at many different locations. *Id.* Single-locus probes are most desirable for forensic use because their banding patterns are easier to interpret. *See generally*, KIRBY, *supra* note 4, at 136–37.

57. KIRBY, *supra* note 4, at 110; Thompson & Ford, *supra* note 5, at 71–72 (the tagged genetic probe acts as a "biological magnet.").

58. KIRBY, *supra* note 4, at 111.

the test.[59] Secondly, when analysts select genetic probes they must consider requirements for uniformity,[60] and how genes mutate.[61] In fact, many considerations regarding probe selection remain to be studied.[62]

6. Autoradiography

Once the genetic probe binds to its complementary strand of DNA located on the nylon membrane, the analyst mounts the membrane between two pieces of x-ray film and leaves it in cold storage for several days.[63] The radioactive tag attached to the probe exposes the film and leaves behind a pattern of bands that correspond to the location of the probes that have bound to the membrane.[64] The resulting print is called an autoradiogram, and it allows the analyst to physically see the results of the DNA profile. The autoradiogram is durable enough to allow inspection by any interested party, including judges and juries who find them extremely useful at trial.[65] Although autoradiography provides the necessary hardcopy to identify the criminal donors, the actual result is not obtained until the other phases are complete.

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59. *Id.* at 2. The DNA from any two persons is more similar than different. Therefore, it is possible for two related persons to share the same allele or alleles at a given location, even if the loci are in highly polymorphic regions. GENETIC WITNESS, *supra* note 7, at 42–43. It is possible, then, for two individuals to have the same DNA profile with respect to the alleles that are examined by a particular testing scheme. Thompson & Ford, *supra* note 5, at 80; GENETIC WITNESS, *supra* note 7, at 66. There is a clear consensus that multiple-probing is a necessity, but no agreement exists as to a standard number of probes that should be used. Janet C. Hoeffel, Note, *The Dark Side of DNA Fingerprinting: Unreliable Scientific Evidence Meets the Criminal Defendant*, 42 STAN. L. REV. 465 (1990).

60. For instance, a uniform system of probes and enzymes is especially desirable if a laboratory is interested in becoming part of national data base. *See generally* KIRBY, *supra* note 4, at 136. Since genetic probes and restriction enzymes both vary by type, and these variances produce different results, it is impossible to compare DNA profiles that have been produced with different systems. Thus, to "facilitate data exchange between analysis centers," laboratories should try to narrow the scope of enzymes and probes used. Such a narrowing also has the affect of simplifying the technical procedures. *Id. See also* NATIONAL RESEARCH COUNCIL, *supra* note 17, at 56.

61. The rate of mutation of an allele can be low; however, selection of a probe that hybridizes an area of DNA that is likely to mutate could, at some point, cause unacceptable results. KIRBY, *supra* note 4, at 136.

62. Some commentators have argued that further studies are needed to determine exactly what the issues are and how they factor into probe selection. *See* Thompson & Ford, *supra* note 5, at 73. Further study of probes may be difficult, however. Free-enterprise barriers and patent restrictions may limit the ability to distribute and study probes uniformly throughout the different laboratories. KIRBY, *supra* note 4, at 141. Procedures of many private laboratories, such as Cellmark and Lifecodes, are not open to review and are generally kept secret, "shielded from scrutiny by the scientific community at large." Thompson & Ford, *supra* note 5, at 59–60. *See also* Hoeffel, *supra* note 59, at 502. The National Academy of Sciences recommends that all probe characteristics should be "readily available for scientific study by any interested person." NATIONAL RESEARCH COUNCIL, *supra* note 17, at 56.

63. KIRBY, *supra* note 4, at 115.

64. *Id.*

65. *See* United States v. Jakobetz, 747 F. Supp. 250, 263 n.26 (D. Vt. 1990), *cert. denied*, 113 S. Ct. 104 (1992). People v. Castro, 545 N.Y.S.2d 985, 995 (Sup. Ct. 1989) ("[A]utorads ... firmly memorialize the experiments conducted ... [and] can be reviewed in an adversarial proceeding to insure that the proper scientific procedures were performed.").

7. Problems With RFLP.

The preceding six steps comprise the extraction and preparation procedures for RFLP analysis. The process is tedious and has many pitfalls along the way that could result in an artifactual (unusable) sample.[66] The forensic analyst is at a distinct disadvantage to her clinical research counterpart. In the clinical research laboratory, DNA testing has built-in consistency checks because DNA from the subject's genetic parents is readily available and allows the analyst to detect any missing or extra bands.[67] This luxury is simply not available to the forensic analyst. RFLP, then, must be done correctly the first time, if it is to be done at all.

B. Polymerase Chain Reaction

RFLP is not the only process by which a result may be obtained, and is not always desirable when there is a small amount of sample. The polymerase chain reaction (PCR) method allows the analyst to take what otherwise would be an insufficient sample and amplify it until there is enough DNA to analyze.[68] PCR allows amplification of degraded DNA from tissues, dried blood, semen stains, and hair follicles and shafts.[69] PCR may even amplify insufficient quantities for use in RFLP analysis.[70] PCR has gained acceptance in some courts,[71] but many of the same concerns about quality that surround RFLP also apply to PCR to an even greater extent.[72]

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66. GENETIC WITNESS, *supra* note 7, at 59–60. Artifactual samples are to be avoided because they may lead to false non-matches or exclusions, and, in rarer cases, false matches or inclusions. *Id.* at 61. False inclusions could occur by human error when the analyst incorrectly places the DNA samples on the gel, or due to degradation, when some bands on the autorad disappear and make a sample appear to be different than it actually is. *Id.* at 60–61.

67. *Id.* at 61. *See* NATIONAL RESEARCH COUNCIL, *supra* note 17, at 53 ("[W]e believe that it is possible to develop reliable forensic DNA typing systems, provided that adequate scientific care is taken to define and characterize the methods."). Research analysts also have adequate sample to perform the analysis repeatedly, and the samples they receive are clean and seldom contaminated. Forensic DNA typing analysts do not enjoy these luxuries. *Id.*

68. Thompson & Ford, *supra* note 5, at 76. PCR is also used in the production of the genetic probes for RFLP analysis. KIRBY, *supra* note 4, at 75. The term PCR, as used in this Note, actually encompasses two procedures, the polymerase chain reaction and allele-specific probe analysis. Allele specific probe analysis, sometimes referred to as "reverse dot-blot hybridization," is designed to be more straightforward than RFLP; it expresses the result in a series of "yes/no" answers. GENETIC WITNESS, *supra* note 7, at 48. A separate blot is prepared for each allele that is to be detected, and then each blot is challenged with a DNA probe that has a key sequence, and developed in a color activating solution. If the allele sought is present, a color will appear. KIRBY, *supra* note 4, at 104–05.

69. *Id.* at 76. Amplification of these samples is possible with error rates as low as 0.25%. PCR is more effective and accurate than traditional molecular cloning systems, where bacteria are used to salvage damaged molecules, possibly introducing artifacts. PCR, however, amplifies only intact molecules, and artifacts are not introduced. *Id.*

70. GENETIC WITNESS, *supra* note 7, at 48. For an excellent overview of PCR and how it works, see generally *id.* at 49. After 20 to 25 cycles, the DNA is reproduced about a million-fold. *Id.*

71. Clarke v. State, 813 S.W.2d 654 (Tex. Ct. App. 1991).

72. PCR is very sensitive. Contamination from other sources, including foreign DNA, can be replicated along with the DNA from the original sample and compound the problem. KIRBY, *supra* note 4, at 78–79. Some have even gone so far as to suggest that the evidentiary and suspect samples should not be stored or amplified in the same room. GENETIC WITNESS, *supra* note 7, at 70. *See generally* NATIONAL RESEARCH COUNCIL, *supra* note 17, at 63–70 (exploring technical issues related to PCR and possible future application of this method).

C. Interpretation of RFLP Autoradiograms

The process of examining two different samples on the autoradiogram and declaring either a match or a non-match is called interpretation.[73] A match means that the two samples are derived from the same source. If visual comparison cannot exclude the suspect sample, the computerized measurement program compares the bands from the known sample with the bands from the questioned sample.[74] If the bands from the two samples are similar,[75] the analyst will declare a match only if both bands fall within a predetermined set of variances from the norm.[76]

Sometimes, variations in the procedure will cause the bands to distort and shift position on the autoradiogram. The analyst should reject the results if the bands move beyond the declared acceptable limits for calling a match.[77] To prevent and detect this phenomenon, a second technican, not involved in the original RFLP extraction and preparation, should interpret the autoradiograms. A second analyst is necessary regardless of whether the interpretation was manual or automated. Furthermore, the laboratory supervisor should review this interpretation for accuracy.[78] Unacceptable variations in the methodology of declaring a match are grounds for inadmissibility of the statistical results.[79]

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73. Thompson & Ford, *supra* note 5, at 74–75.

74. The forensic science community agrees that computer-aided measurement must follow up visual comparison resulting in a called match. GENETIC WITNESS, *supra* note 7, at 66. The forensic science community, however, is not in consensus regarding the standard level of operator involvement in computer aided measurement. *Id.* Although computers can differentiate banding patterns that would otherwise be impossible to separate using the naked eye, they are susceptible to "background noise," which may create a result where none was anticipated. *Id.* at 18. Despite this problem with computers, the general opinion is that visual matching alone is "not appropriate." *See* KIRBY, *supra* note 4, at 116. Without the aid of the computer, the analyst is forced to "eyeball" the banding patterns on the autorad, resulting in subjective interpretations and inconsistent results from analyst to analyst. GENETIC WITNESS, *supra* note 7, at 18.

75. *See generally* KIRBY, *supra* note 4, at 159. The size of each band is indexed according to size markers, also located on the autorad, allowing the analyst to approximate the length, in base pairs, of the bands from the evidentiary sample. *Id.*

76. Thompson & Ford, *supra* note 5, at 87–88. The authors refer to this as a "latitude of acceptance." *Id.* at 87. The acceptance window may depend upon who the analyst is and where she is employed. Police criminalists, for instance, are typically law enforcement employees who may feel an obligation to help the prosecution make its case. These individuals are likely to have a different acceptability threshold than an independently employed research technician. Moreover, in some instances, the presence of abnormalities may actually result in an inadvertent widening of the window of acceptability by the analyst. In other words, the analyst adjusts her judgment to compensate for the irregularities. *Id.* at 87–89, 91. These subjective variations tend to be ignored at pre-trial admissibility hearings, however, and are passed off as "fodder for effective cross-examination" for the jury to consider. United States v. Jakobetz, 747 F. Supp. 250, 257 (D. Vt. 1990), *cert. denied*, 113 S. Ct. 104 (1992).

77. KIRBY, *supra* note 4, at 120. Variations in the RFLP extraction and preparation technique, electrophoresis resolution, and gel mobility are also factors that affect measurement precision during the interpretation phase. *Id.* at 116. Computerized "fudge factors" have been used to compensate for these shifts, but their use remains clouded by controversy, primarily because these factors have not been subjected to adequate peer review. *Id. See also* Thompson & Ford, *supra* note 5, at 76.

78. Beeler & Wiebe, *supra* note 35, at 927–28.

79. *See, e.g.*, People v. Castro, 545 N.Y.S.2d 985, 998 (Sup. Ct. 1989).

D. Population Genetics

A match between two samples does not necessarily mean that the samples are from the same source. The two samples could also appear the same as a matter of mere coincidence.[80] The process of assigning a numerical probability that either of these alternatives has occurred at the exclusion of the other is called "population genetics."[81] The probability estimate is given in terms of the chance of finding a random member of the population, not a suspect, who has a matching profile.

Calculation of the population frequency of a DNA pattern consists generally of two steps. First, the analyst separates the DNA banding pattern that appears on the autoradiogram into its component bands, and determines the frequency of each individual band in the respective suspect's ethnic group, or population. Statistics dervied from the first step help determine the suspect's frequency in the population of the entire DNA pattern.[82]

Once the frequency of each band is established for each gene and probe used, and for each population, the geneticist uses these statistics to estimate the probability that another person, the same race as the suspect, picked at random, would have a DNA profile matching the defendant's. This calculation rests upon the assumption that humans mate completely randomly, and do not form racial or ethnic sub-groups. When random mating occurs, the occurrence of the alleles is independent; that is, the frequency of one studied allele (or gene version) will not influence the frequency of any of the other studied alleles. Given these assumptions, one applies the product rule.[83]

This method of determining the frequency of a profile relies heavily upon the assumptions that the alleles that comprise the profiles are independent and

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80. NATIONAL RESEARCH COUNCIL, *supra* note 17, at 74.

81. *See, e.g.*, GENETIC WITNESS, *supra* note 7, at 8 (population genetics provides meaning and numerical weight to the frequencies of various DNA markers in the population).

82. *Id.* at 66. To define the frequency of an individual allele in the population, the FBI uses a process called "binning." KIRBY, *supra* note 4, at 159. Fragment size standards define the boundaries of each bin. Sample population alleles are placed in the bins according to the size fragments (determined by the restriction enzyme used) on which they reside, and the analyst calculates the frequency of occurrence of each allele in each bin. An allele from a suspect or a crime sample is assigned the frequency of the bin within which the allele falls. *Id.*

The analyst calculates the frequency of each gene occurring in each bin; to compensate for racial sub-grouping, this calculation is repeated for each population. Although the different populations may be easy to determine, classifying which subgroups fall into which populations may be difficult. For example, the Hispanic population may include all Puerto Ricans, Mexican nationals, Cubans, or El Salvadorans. Like variations occur for the Native American data bases, and the Oriental data bases as well. GENETIC WITNESS, *supra* note 7, at 68.

83. Independence means that the occurrence of event A does not influence the probability of occurrence for event B. If two or more events are independent, then the joint probability of A and B occurring together is the product of the probability of A and the probability of B. For example, at locus M, the probability of detecting allele A is 0.2 (20%), and at locus R, the probability of detecting allele B is 0.3 (30%). Assuming the occurrence of each allele at each locus is independent, the product rule is applied, to wit: p(A) 0.2 x p(B) 0.3 = 0.06. *Id.* A truly valid assumption of independence would require at least 30 billion patterns of DNA to be studied, of which no pattern may be more or less likely to occur than any other. Thompson & Ford, *supra* note 5, at 83.

that humans mate completely randomly without regard to race.[84] These assumptions are weak,[85] and relying upon them results in making a match seem rarer than it really is. As a result, the criminal defendant may be unduly prejudiced.[86] Thus, the continued use of the product rule based upon genetic independence and equilibrium through random mating is clearly not sound.

Since valid probability calculations must consider the variations between actual population statistics and the mathematical norm,[87] the forensic community needs to conduct extensive testing of the general population and the various ethnic subgroups in order to better catalog these differences.[88] Observers, however, have difficulty defining just what ethnic sub-populations need to be studied.[89] Clearly, the demonstrable need for further study of ethnic sub-populations complicates the population genetics element of DNA typing in criminal trials.[90]

E. Quality Laboratory Practice

The DNA typing process is intricate and complicated. The procedure may require several days or weeks to complete. Therefore, a planned and defined written procedure, or protocol, which spans the entire testing process is necessary.[91] Quality laboratory practice is a broad definition of quality control, and it encompasses the work done in the RFLP steps, the interpretation phase, and the population genetics phase. In addition, quality laboratory practice provides evaluation and control by authorities outside the laboratory. This section identifies some crucial issues relating to quality laboratory practice, and then discusses current and future methods available to deal with these important issues.

1. Necessity of Quality Laboratory Practice.

DNA typing consists of three separate procedures. Each of these three procedures relies heavily upon the proper performance of the other procedures. Therefore, errors or improper adherence to protocol in any one

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84. GENETIC WITNESS, *supra* note 7, at 67–68. By altering the assumptions, the frequency estimates in one Manhattan murder trial generated results ranging from 1 in 500 to 1 in 739 billion. NATIONAL RESEARCH COUNCIL, *supra* note 17, at 75.

85. "In fact, alleles are not randomly distributed among individuals. *Certain alleles clearly concentrate within specific ethnic groups* ...." GENETIC WITNESS, *supra* note 7, at 68 (emphasis supplied).

86. *Id.* at 67.

87. KIRBY, *supra* note 4, at 154.

88. *See* Beeler & Wiebe, *supra* note 35, at 925; NATIONAL RESEARCH COUNCIL, *supra* note 17, at 79–80. This testing has not been done. The Office of Technology Assessment concedes that it does not know the magnitude of mathematical compensation that needs to be made to account for the variations from the genetic norm. GENETIC WITNESS, *supra* note 7, at 68. Moreover, studies conducted by the commercial laboratories, Cellmark and Lifecodes, were small and drew upon non-random samples, and thus failed to adequately address the unusual occurrences of bands within certain sub-populations. *See* Thompson & Ford, *supra* note 5, at 84, 86. Although the FBI analysts have attempted to brush off these differences, claiming that the profiles between the various populations were "amazingly similar," they were unable to support these conclusions with any hard scientific evidence. United States v. Jakobetz, 747 F. Supp. 250, 260–61 (D. Vt. 1990), *cert. denied,* 113 S. Ct. 104 (1992).

89. *See supra* note 82.

90. *See generally* NATIONAL RESEARCH COUNCIL, *supra* note 17, at 82.

91. *Id.* at 72.

procedure may compromise the validity of the entire testing scheme.[92] The ultimate goal of quality laboratory practice, then, is to eliminate false negatives and false positives.[93] It is important in DNA typing analysis that laboratories scrutinize their sample handling and technique, laboratory controls and standards, and attempt to minimize differences in analyst judgment and match criteria.[94]

a. Sample Handling Technique

In DNA testing, the quality of the result is only as good as the quality of the sample received.[95] Because DNA is susceptible to degradation and degraded DNA cannot be analyzed, there must be meticulous sample handling techniques throughout the entire chain of custody, including the field[96] and the laboratory.[97]

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92. *See* Thompson & Ford, *supra* note 5, at 65. The FBI's procedures have generated abnormalities and inconsistencies in data that it has had difficulty explaining. *See Jakobetz*, 747 F. Supp. at 261. In order to develop its Caucasian data base, the FBI ran the DNA profiles of 225 of its agents. Later, when the FBI reran the same 225 blood samples, ten of the 400 alleles did not provide a match with the first set of autorads. Moreover, some alleles settled in different bins than those in which they had landed during the first run. *Id.*

Some of the commercial laboratories exhibit an even worse track record. *See, e.g.*, CALIFORNIA ASSOCIATION OF CRIME LABORATORY DIRECTORS (CACLD), REPORT NO. 6 [hereinafter CACLD REPORT NO. 6] (on file with the *Arizona Law Review*). CACLD sent three sets of 50 samples each to Lifecodes, Cetus, and Cellmark in 1987. Cetus reported one false match, and Cellmark reported two false matches in its first report, but was allowed to submit a second report, which contained only one error. *Id.* at 5 n.***. *See also* Record at 872–81, People v. Axell, No. CR 23911 (Super. Ct. Ventura City, Cal. 1989) (testimony of Margaret Kuo, President, California Association of Crime Laboratory Directors) (on file with the *Arizona Law Review*). The first report submitted by Cellmark to CACLD in March 1988 was unintelligible. *Id.* at 876. The CACLD received a second report in May 1988, which contained only one error. CACLD REPORT NO. 6, *supra*, at 5. A second batch of proficiency samples was sent to the laboratories in July, 1988. Lifecodes made no incorrect matches. *Id.* at 6. However, Cellmark once again incorrectly matched one of the 50 samples submitted to it. *See* Letter from Margaret Kuo, President, CACLD, to Dr. Dan Garner, Cellmark (February 22, 1990) (regarding Cellmark's performance on July 1988 proficiency test) (on file with the *Arizona Law Review*). *See also* NATIONAL RESEARCH COUNCIL, *supra* note 17, at 88–89.

93. A false negative result indicates that a conclusion was made that a match between two specimens did not exist when, in fact, the specimens were obtained from the same source. A false positive result indicates that a conclusion was made that a match between two samples did exist, when, in fact, the samples were obtained from different sources. KIRBY, *supra* note 5, at 180.

94. Analyst judgment and match criteria are discussed *supra* at notes 73–90 and accompanying text.

95. KIRBY, *supra* note 4, at 52.

96. Specimen collection and handling is an essential part of DNA profiling. Those individuals who collect this evidence should be familiar with the analytical principles of DNA typing. *Id.* at 53. Frequently, laboratory personnel are not present at the crime scene when evidence is collected, and other law enforcement personnel who are less familiar with the level of care required for this sensitive evidence may handle it carelessly and ruin the sample before it ever reaches the laboratory. Therefore, officers trained in DNA profiling who work in the field play an important role in reducing errors at the laboratory. *See generally* KIRBY, *supra* note 4, at 53–55; GENETIC WITNESS, *supra* note 7, at 77.

97. Sample handling techniques are important at the laboratory where several analysts are working in tandem. Variations in technique from analyst to analyst are capable of causing print differences. Thompson & Ford, *supra* note 5, at 88–89. Careless laboratory procedures may also result in false incrimination. False incrimination may result from such analyst errors as placing the sample in the wrong location on the gel, *id.* at 95, or carelessly using transfer tubes and other laboratory equipment, thereby inadvertently contaminating the probe DNA. *Id.* at 96.

Unfortunately, sample submission and handling errors are very difficult to detect.[98]

b. Controls and Standards

The use of controls and standards may improve the consistency and accuracy of the method. Controls are known samples that are run under the same conditions as the questioned sample. If the results for the controls conform to expected norms, the unknown result is also presumed accurate.[99] A variety of simple and widely accepted procedures are available to correct errors and prevent unreadable results, or artifacts, that can arise during DNA testing.[100]

The terms "controls" and "standards" are sometimes used interchangeably.[101] However, this is misleading. While a control accompanies each specific run of a procedure, standards are the "rules" by which technicians conduct entire analysis schemes.[102] Standards may be divided up into two basic types—technical standards[103] and operational standards.[104] However, "[s]etting standards for forensic applications of DNA testing is the most controversial and unsettled issue."[105] Experts cannot agree upon how to use

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Analyst technique with respect to probe contamination is especially important with regards to single locus probes and is likely to become a major issue at trial. *Id.*

98. *See* Jane E. Hanner, Note, *DNA Fingerprinting: Evidence of the Future*, 79 KY. L.J. 415, 434 (1991). For example, failure to leave a blank lane on the gel plate between the suspect and the control sample could cause leakage between the lanes, resulting in an incorrect conclusion. NATIONAL RESEARCH COUNCIL, *supra* note 17, at 59.

99. GENETIC WITNESS, *supra* note 7, at 62–63. *See also* AMERICAN SOCIETY OF CRIME LABORATORY DIRECTORS, LABORATORY ACCREDITATION BOARD MANUAL at Glossary–1 (1982) [hereinafter ASCLD], which defines a control as "[a] standard of comparison for verifying or checking the findings of an experiment." *Id.*

100. GENETIC WITNESS, *supra* note 7, at 64. Examples of controls are: control human DNA (verifies that electrophoresis and hybridization occurred as expected); molecular size markers (provide a molecular ruler to measure and verify sample fragment size and test for uniformity of electrophoresis); internal lane controls, tests for incomplete stripping (assure that all non-hybridized probes are removed before reprobing); and plasmid DNA controls (which ferret out non-human DNA contamination). *Id. See, e.g., id.* at 63 (controlling for potential problems); KIRBY, *supra* note 4, at 182.

101. For example a reference standard may be "[a] sample acquired or prepared that has known properties for the purpose of calibrating equipment *and for use as a control in experiments.*" ASCLD, *supra* note 99, at Glossary–5. (emphasis supplied).

102. Standards may be "[s]tatements which establish acceptable levels of performance, excellence or attainment in that particular activity." *Id.* Standards to ensure laboratory quality should not be confused with developing a uniform national system. GENETIC WITNESS, *supra* note 7, at 83.

103. Technical standards include proper reagent and gel controls to insure that contamination has not occurred, regulation of electrophoresis conditions, rules used to match DNA banding patterns, rules regarding the extent to which computer-assisted matching should be permitted, and rules regarding the use of population data to compute the likelihood of matches. *Id.* at 10.

104. Operational standards include the recordkeeping and proficiency testing of the laboratory mechanism and personnel. Operational standards are more controversial than technical standards because they generally involve the imposition of recommendations by outside groups, which usually meets with stiff resistance from within. *Id.* at 82.

105. *Id.* at 10.

standards or who should develop them.[106] This lack of consensus is currently placing forensic DNA typing in serious jeopardy.[107]

2. Elements of Quality Laboratory Practice

Quality laboratory practice consists of two basic elements: quality control and quality assurance. These two elements, used in a comprehensive program, can minimize DNA typing problems but cannot eliminate them entirely.[108]

a. Quality Control

Quality control is one aspect of quality assurance. Quality control is defined as the "steps taken by a laboratory to produce consistent, interpretable results each time the test is performed."[109] The proponent's expert witness generally must testify as to quality control in the laboratory. She must verify that she analyzed the correct specimen and performed tests to indicate the degree of DNA degradation and contamination. She should also ensure that she ran a well-controlled experiment and that she did not deviate from the authorized laboratory protocol.[110] To aid her testimony, the laboratory may use a quality control system based upon mathematical computations.[111]

b. Quality Assurance

Quality assurance programs offer tangible proof that the laboratory performs quality control. Tangible proof includes internal and external proficiency testing, external inspections, written laboratory procedure and

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106. *Id.* at 82. The members of the forensic science community, while acknowledging the need for standards, resent the formulation of these standards by members of other scientific communities who are not familiar with forensic casework. In the other camp, molecular geneticists believe that their 20 year experience with recombinant DNA research and their vast research base place them in the superior position to determine how DNA tests should be implemented in the forensic laboratory. Many believe that an independent commission is the best method for promulgating both technical and operational standards. *Id.* The National Academy of Science report concurs in this judgment and calls for the formulation of a National Committee on Forensic DNA Typing (NCFDT). Because of the scientific nature of this body, the NAS report calls for its affiliation with a non-law enforcement body, such as the National Institute of Health, or the National Institute on Standards and Technology. NATIONAL RESEARCH COUNCIL, *supra* note 17, at 70–71.

107. "Challenges to the reliability of DNA tests will mount unless the issue of standards is addressed." GENETIC WITNESS, *supra* note 7, at 8.

108. "[N]o amount of standardization, standard setting, or quality assurance can be substituted for appropriate interpretation and analysis by a forensic scientist during the course of an individual case." *Id.* at 14.

109. *Id.* at 71. These steps are somewhat akin to the steps taken by a manufacturer to prevent production flaws. *See generally* W. PAGE KEETON ET AL., THE LAW OF TORTS § 99, at 694–97 (5th ed. 1984).

110. KIRBY, *supra* note 4, at 179–80.

111. One example of this is the Shewhart quality control system, which establishes rejection and acceptance rules based upon relatively simple mathematical calculations. KIRBY, *supra* note 4, at 185. *See generally* WALTER A. SHEWHART, ECONOMIC CONTROL OF QUALITY OF MANUFACTURED PRODUCT (1931); James O. Westgard et al., *A Multirule Shewhart Chart for Quality Control in Clinical Chemistry*, 27 CLINICAL CHEMISTRY 493 (1981).

policy, and certification and accreditation.[112] Voluntary professional associations may play a significant part in the quality assurance programs of the forensic laboratory.[113] These professional organizations, together with their member laboratories, provide proficiency tests with independent verification of the results,[114] promulgate written protocols,[115] and perform accreditation and certification functions.[116]

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112. *See* GENETIC WITNESS, *supra* note 7, at 71; KIRBY, *supra* note 4, at 179. These are similar to the actions taken by a manufacturer to eliminate design flaws or "generic risks." *See* KEETON ET. AL., *supra* note 109, § 99, at 698–702.

113. GENETIC WITNESS, *supra* note 7, at 72. Such organizations include the American Academy of Forensic Sciences (AAFS), the American Society of Crime Laboratory Directors (ASCLD), the California Association of Criminalists (CAC), California Association of Crime Laboratory Directors (CACLD), and other non-forensic academic groups such as American Assocation of Blood Banks (AABB), the American Society for Forensic Haematogenetics (ISFH), and even the Electrophoresis Society. *Id.* Laboratory membership in these organizations is strangely lacking. *Id.* at 78. As of May 1989, only 22% of the nation's crime laboratories had been accredited during ASCLD's seven years in operation, while 39% of the parentage testing laboratories have been accredited with the five-year old AABB program. *Id. See also* NATIONAL RESEARCH COUNCIL, *supra* note 17, at 102–03. Because courts are reluctant to require membership with an accreditation body, growth in these programs with respect to DNA typing remains slow. *Id.* at 103, 106.

114. Proficiency testing of laboratory personnel may be either "open" or "blind." Technical Working Group on DNA Analysis Methods, *Guidelines for a Quality Assurance Program for DNA Restriction Fragment Length Polymorphism Analysis*, 16 CRIME LABORATORY DIG. 40, 53 (1989) [hereinafter *Guidelines*]. Many commentators prefer blind proficiency tests because the analyst is not aware she is being tested, and thus does not make non-routine adjustments in her behavior as a result. *See* William F. Thompson, *Are Juries Capable of Evaluating Statistical Evidence?*, 52 L. & CONTEMP. PROBS. 9, 22 (1989); Beeler & Wiebe, *supra* note 35, at 928; NATIONAL RESEARCH COUNCIL, *supra* note 17, at 55 ("no laboratory should let its results with a new DNA typing method be used in court, unless it has undergone proficiency studies *via blind trials.*") (emphasis supplied). *But see* United States v. Jakobetz, 747 F. Supp. 250, 257 (D. Vt. 1990), *cert. denied*, 113 S. Ct. 104 (1992) ("the court does not believe the lack [of blind proficiency testing] substantially undermines the FBI procedures currently in place."). Blind proficiency testing of laboratory personnel has no substitute; validation studies conducted by independent evaluators simply do not respond to analyst errors. Thompson & Ford, *supra* note 5, at 69. A validation study only verifies the efficacy of the procedure and assumes it is performed by a competent analyst; blind proficiency testing, however, reflects the individual analyst's *understanding* and the laboratory's application of the procedure. NATIONAL RESEARCH COUNCIL, *supra* note 17, at 55.

115. All laboratories should follow a specific written protocol that covers the entire process from beginning to end, so that when an audit and inspection is conducted, the reviewers may validate the procedures using a "traceable audit trail." *See* Beeler & Wiebe, *supra* note 35, at 927. *See also Guidelines*, *supra* note 114, at 46. ("This documentation *must* describe in explicit detail the protocol currently used for the analytical testing of DNA.").

116. The accreditation and certification process includes laboratory inspections and audits, validation studies of the techniques used, and requirements regarding minimal education credentials and ongoing training of laboratory personnel. *See Guidelines*, *supra* note 114, at 44–54. Current programs fail to guarantee reliability because participation in them is completely voluntary. GENETIC WITNESS, *supra* note 7, at 12. State regulation, though possible, is non-existent. *Id.* at 75–76. To date, no state has enacted licensing statutes for publicly operated crime laboratories or private DNA typing laboratories. *Id.* Ironically, blood alcohol testing instruments are more effectively regulated than DNA testing laboratories. *See* Fuenning v. Superior Court, 139 Ariz. 590, 602, 680 P.2d 121, 132 (1983) (rejecting the prosecution's breathalyzer tests because local police failed to comply with objective and uniform state standards). The National Academy of Sciences recommends a mandatory licensing scheme imposed by the federal government. NATIONAL RESEARCH COUNCIL, *supra* note 17, at 100–01.

As the foregoing indicates, quality laboratory practice is a crucial issue that needs to be explored further. Outside-implemented programs designed to prevent sample destruction and laboratory errors are insufficient to handle the growing caseload.[117] No scientific consensus exists regarding controls and standards, which are essential in consistently achieving a reliable result. And because membership in professional accreditation organizations is voluntary, effective quality assurance in the current laboratory system is clearly lacking in some laboratories.[118] Therefore, the courts should require that the forensic science community or a neutral government body address this issue quickly before continuing to allow DNA typing evidence at trial.[119]

II. TRADITIONAL EVIDENTIARY EVALUATION TECHNIQUES

The admissibility of DNA typing evidence is a question of law.[120] When courts encounter novel scientific techniques, they may utilize either the rule laid out in *Frye v. United States*[121] or the "relevancy standard" embodied in the *Federal Rules of Evidence*.[122] Although the legal commentators debate the differences between the two standards and the advantages of applying one over the other, the two standards are essentially the same—each requires a proper foundation prior to the admission of scientific evidence.[123] The ideal goal of each standard is to prevent the results of "speculative or conjectural testing" from reaching the jury at trial.[124]

Each standard depends upon "the validity of the underlying principle, ... the validity of the technique applying that principle, and ... the proper application of the technique on a particular occasion."[125] Judges usually consider the validity of the principle and the technique when they evaluate new evidence at the pre-trial admissibility hearing.[126] Juries are left to deal with the broader issues surrounding proper application of the technique on a

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117. GENETIC WITNESS, *supra* note 7, at 77. *See also supra* note 114.

118. *See supra* note 116. According to the National Academy of Science, laboratory accreditation should be mandatory. NATIONAL RESEARCH COUNCIL, *supra* note 17, at 100.

119. *Id.* at 106–07. The National Research Council continued: "Courts should view the absence of appropriate accreditation as constituting a prima facie case that the laboratory has not complied with generally accepted standards." *Id.* at 107.

120. Melson, *supra* note 13, at 192.

121. 293 F. 1013 (D.C. Cir. 1923).

122. *See* FED. R. EVID. 401, 402, 403, and 702.

123. United States v. Two Bulls, 918 F.2d 56, 60 (8th Cir. 1990), *vacated for reh'g en banc*, 925 F.2d 1127 (8th Cir. 1991) (not reargued due to death of appellant). *See also* Steven Saltzburg, Frye *and Alternatives, Symposium on Science and Rules of Evidence*, 99 F.R.D. 208 (1983). Professor Saltzburg writes, "it is not very helpful to debate the question whether *Frye* or a relevance approach to scientific evidence is preferable. The two approaches are essentially the same, despite the frequency with which they are assumed to differ." *Id.* at 209.

124. *Two Bulls*, 918 F.2d at 60.

125. Paul C. Giannelli, *The Admissibility of Novel Scientific Evidence:* Frye v. United States, *a Half-Century Later*, 80 COLUM. L. REV. 1197, 1201 (1980). *See also* Melson, *supra* note 13, at 196; People v. Castro, 545 N.Y.S.2d 985, 987 (Sup. Ct. 1989).

126. Giannelli, *supra* note 125, at 1202.

particular occasion.[127] Once the court has established reliability of the novel technique, it may take judicial notice of the principle and the technique, but demand further inquiries regarding the proper application of the technique to the case before it.[128]

Courts must be careful, regardless of the standard they utilize, to fully consider the admissibility of DNA typing evidence. As Professor Moenssens notes, the stakes can be very high:

> In criminal cases, where an individual's freedom is at stake, courts certainly ought to be very cautious in admitting evidence based upon insufficiently tested or verified premises, especially where the evidence seeks to establish the ultimate issue in the case—the identification of the accused as the perpetrator of the offense.[129]

A. United States v. Frye as an Evidentiary Standard

1. The Theory Behind Frye

The *Frye* standard, often referred to as the "general acceptance test," is the oldest standard of admissibility for novel scientific techniques in use today.[130] It was the first standard in which the general acceptance of the scientific community was the test for admissibility.[131] Despite its long-standing use, courts interpret the *Frye* test unevenly, often adopting it in name only for whatever standard the judge may decide to embrace.[132] The end result is that there are several *Frye* tests, not one. Despite this disparity, the *Frye* standard still stands for the principle that the testimony and the approval of one expert witness is insufficient to admit evidence based on a novel scientific technique into a court of law.[133]

The main concern of *Frye* is that no untested scientific theory be used at trial without being passed upon by "a minimal reserve of experts."[134] This way, those individuals with superior knowledge in relevant fields "have the

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127. These factors include the condition of the instruments used in the procedure, the maintenance and compliance with written protocol and procedures, and the qualifications of the technician applying the technique and interpreting the results. *Id.* at 1201–02.

128. *Id.* at 1202.

129. MOENSSENS ET AL., *supra* note 6, at 7.

130. *Id.* at 5.

131. Paul C. Giannelli, *Background Paper Prepared for the National Conference of Lawyers and Scientists, Symposium on Science and the Rules of Evidence*, 99 F.R.D. 189 (1983).

132. Giannelli, *supra* note 125, at 1221.

133. United States v. Two Bulls, 918 F.2d 56, 61 (8th Cir. 1990), *vacated for reh'g en banc*, 925 F.2d 1127 (8th Cir. 1991). The Court of Appeals in *Frye* adopted the general acceptance standard and applied it to the submission of a crude polygraph into evidence at a murder trial. The court wrote:

> 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 courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, *the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs.*

United States v. Frye, 293 F. 1013, 1014 (D.C. Cir. 1923) (emphasis supplied).

134. United States v. Addison, 498 F.2d 741, 744 (D.C. Cir. 1974).

determinative voice" regarding admissibility.[135] The relevant scientific community's[136] acceptance of a novel scientific technique gives the technique a presumption of reliability.[137] This presumption of reliability, however, depends on adequate experimentation and testing of the new technique so that the relevant scientific community has substantially eliminated theoretical, technical or practical errors.[138]

The level of general acceptance necessary for a novel scientific technique to be admissible at trial is unclear under the *Frye* standard. In addition to the opposing parties' expert testimony, the court may also wish to examine the scientific literature to ascertain the requisite level of acceptance.[139] Reliance and citation of this scientific literature, as a supplement to courtroom testimony, serves as a form of judicial notice. The court may utilize this literature to determine acceptance, or more likely, lack of acceptance, when making an ultimate decision under *Frye*.[140]

2. Frye's Deficiencies

Frye's acceptance standard has its detractors. Many critics reject the underlying assumption that acceptance in the scientific community equals reliability, and others assail the inquiries into the relevant fields and the level of acceptance necessary as being too vague and difficult to apply uniformly.[141]

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135. *Id.* at 743–44.

136. Courts dealing with DNA typing evidence have particular difficulty pigeonholing the technique into a relevant scientific community. *See* United States v. Jakobetz, 747 F. Supp. 250, 256 (D. Vt. 1990), *cert. denied,* 113 S. Ct. 104 (1992) (examining molecular biology and population genetics); People v. Wesley, 533 N.Y.S.2d, 643, 645 (Co. Ct. 1988) (molecular biology, population genetics, and "other diverse areas of genetics and human genetics ....").

137. Thompson & Ford, *supra* note 5, at 53; Beeler & Wiebe, *supra* note 35, at 933; Melson, *supra* note 13, at 193. With respect to DNA testing, the Office of Technology Assessment points to several factors indicating reliability including procedures, laboratory performance, laboratory recordkeeping, and quality control and quality assurance. GENETIC WITNESS, *supra* note 7, at 7.

138. Giannelli, *supra* note 125, at 1225. Extensive validation studies conducted subsequent to admission voids this presumption. Validation studies and proficiency testing conducted prior to admission of the evidence are the only acceptable alternatives. *Id.* at 1249. *See* Saltzburg, *supra* note 123, at 216. Professor Saltzburg continues, "It is one thing to accept the risk of human error by jurors when the errors are essentially unavoidable and probably not discernible. It is another to permit a 'scientific' claim when that claim might later be shown to be wrong." *Id.* at 213.

139. Even scientific literature that is written by commercial laboratories or individual proponents of the method has been subjected to substantial peer review and criticism. This literature is quite useful in determining the exact level of acceptance in the relevant field, notwithstanding the partisan statements made by the retained experts in the courtroom. Beeler & Wiebe, *supra* note 35, at 945–46. *See also* Melson, *supra* note 13, at 195.

140. Giannelli, *supra* note 125, at 1217–18. Where the experts appear to believe that general acceptance has been achieved, the court may take notice of the fact that the scientific literature is not in agreement on the issue, and may rule a novel technique inadmissible under *Frye. Id.* at 1218. Once the reliability of the technique has been established, the courts may take judicial notice of both the technique itself and the courts that have accepted that technique. MOENSSENS ET AL., *supra* note 6, at 8. Judicial notice absolves proponents of establishing the general acceptance of these items at future trials. Melson, *supra* note 13, at 204.

141. Professor Moenssens writes: "Many of the deficiencies in our fact finding process on scientific issues are inherent in the adversarial system and result from factors other than the Frye test. The general acceptance rule, however, does not ameliorate them; it exacerbates them." MOENSSENS ET AL., *supra* note 6, at 10. *See also* John W. Strong, *Questions Affecting the*

Frye courts are concerned that jurors tend to be swayed too easily by the opinion testimony of skilled experts. Therefore, reliance on expert testimony is proper only if general acceptance by experts in the field indicates reliability. Actual experience, however, indicates that this may not be so. "'[G]eneral acceptance' under *Frye* does not necessarily result in 'reliability' of the test used."[142] A finding of general acceptance simply does not provide an adequate critical examination of other issues relating to the conduct of the laboratory personnel.[143] The dangers of placing the acceptance cart before the testing horse is illustrated in the ugly history of prior novel evidence debacles.[144] Reliability can and should be established without a showing of general acceptance, because general acceptance in and of itself does little to screen out unreliable techniques.[145] Because the legal community at large suffers from scientific illiteracy, the courts are unequipped and therefore unlikely to reject techniques that are not properly validated and will tend to admit the unproven techniques without objection.[146]

A second major difficulty with the *Frye* standard is that not all scientific techniques fit neatly into discrete disciplines; a particular procedure may span many different schools and applications.[147] The court's selection of the proper fields is vital to the case. If the range of disciplines is too broad, experts may offer opinions on unproven techniques even though their knowledge may be limited, and the court risks being deluged with expert testimony of limited probative value.[148] On the other hand, if the range of disciplines is too narrow, the court must rely upon the testimony of a mere handful of experts. The ultimate hazard of this is an erroneous conclusion based upon inadequate testimony.[149] The individual judge, therefore, has a substantial, if not dispositive, impact on admissibility. The dangers of this large amount of discretion include the manipulation of the case to address the perceived needs

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Admissibility of Scientific Evidence, 1970 U. ILL. L.F. 1, 11 (1970) ("The resulting standard, something greater than acceptance by the expert himself but less than acceptance by all experts in the field, is obviously somewhat lacking in definiteness.").

142. MOENSSENS ET AL., *supra* note 6, at 6.

143. People v. Castro, 454 N.Y.S.2d 985, 987 (Sup. Ct. 1989). The *Castro* court continued, "[T]he test obscures critical problems in the use of a particular technique." *Id. See also* State v. Schwartz, 447 N.W.2d 422 (Minn. 1989) (laboratory failed to comply with adequate quality assurance guidelines). Such issues as sample switching, technician qualifications, and the steps taken to counteract degradation and contamination during a particular run are not likely to be explored in a pure general acceptance paradigm.

144. The *Frye* model blindly assumes that adequate testing by the scientific community has already been performed prior to acceptance. Giannelli, *supra* note 125, at 1224–25. This assumption is erroneous. For example, the paraffin test, used primarily to detect gunshot residues on the hands of the accused, was quickly admitted and used extensively until the test's non-specificity (cross reactions with substances other than gunpowder residues) was discovered through subsequent empirical testing. *Id.* at 1227.

145. Giannelli, *supra* note 125, at 1223.

146. MOENSSENS ET AL., *supra* note 6, at 7 n.13.

147. Giannelli, *supra* note 131, at 192.

148. For instance, DNA testing, although its origins are in academic research, has substantial forensic capability. Although academic professionals are able to render accurate testimony about the theory, they are not likely to be as knowledgeable as a forensic expert about the vagaries of forensic applications. *See, e.g., supra* note 67.

149. Giannelli, *supra* note 125, at 1209–10.

of the parties and others,[150] and a wide variety of decisions by different courts on the same issue.[151]

The thorniest dilemma regarding the *Frye* standard centers around how much acceptance is enough to constitute "general acceptance."[152] The general acceptance standards are ambiguous and interpreting their true meaning often invites unnecessary delay in the acceptance of the method.[153] The scope of acceptance that is necessary to satisfy *Frye* has been the subject of numerous differences in judicial opinion. Deciding whether the underlying principle must be accepted only by the specific community applying the technique, or whether the theory must be accepted by the scientific community at large, causes the most difficulty.[154]

There is no specific percentage of scientists in the field who must accept the technique. The consensus need not be unanimous, but must lie between a simple and a strong majority.[155] A court that examines the number of experts on either side runs the risk of playing a nose-counting game. This could result in finding general acceptance where none exists, especially if the judge neglects to inspect the scientific literature,[156] or fails to appoint an independent expert for the court.[157] In addition, lack of opposition is not equivalent to general acceptance.[158] Unchallenged or unstudied evidence may be admitted, even if it is inherently inaccurate. Unfortunately, the trier of fact will often rely on such evidence.

Although determining a consensus is a major difficulty inherent in the *Frye* standard, the variations in levels of acceptance from one scientific community to another scientific community offer further problems. For example, commercial researchers originally developed the DNA typing methodology. The acceptance of this technique by the community of academic and commercial research scientists who create it will not be the equivalent of

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150. *Compare* Kelly v. State, 792 S.W.2d 579 (Tex. Crim. App. 1990) (admitting whole result and convicting defendant) *with* State v. Woodall, 385 S.E.2d 253 (W. Va. 1989) (rejecting possibly exculpatory "no-result" DNA test offered by defendant).

151. *See, e.g.*, Caldwell v. State, 393 S.E.2d 436 (Ga. 1990) (rejecting population genetics and allowing the result itself); State v. Schwartz, 447 N.W.2d 422 (Minn. 1989) (rejecting the whole testing result); Glover v. State, 787 S.W. 544 (Tex. Ct. App. 1990) (admitting DNA test results in whole).

152. Frye v. United States, 293 F. 1013, 1014 (D.C. Cir. 1923).

153. Thompson & Ford, *supra* note 5, at 54–55. *See* Coppolino v. State, 223 So. 2d 68, 75 (Fla. Dist. Ct. App. 1968) ("Society need not tolerate homicide until there develops a body of medical literature about some particular lethal agent.").

154. Melson, *supra* note 13, at 194. *See also* Snowden v. State, 574 So. 2d 960 (Ala. Crim. App. 1990) (reliable and generally accepted in the scientific community); State v. Pennington, 393 S.E.2d 847 (N.C. 1990) (whether the evidence was reliable and the result based upon scientifically established methods that have gained general acceptance); Glover v. State, 787 S.W. 2d 544 (Tex. Crim. App. 1990) (whether technique was reliable and had gained general acceptance in the scientific community in the particular field).

155. Giannelli, *supra* note 125, at 1210–11; United States v. Jakobetz, 747 F. Supp. 250, 259 (D. Vt. 1990), *cert. denied*, 113 S. Ct. 104 (1992).

156. *See supra* note 140.

157. FED. R. EVID. 706.

158. MOENSSENS ET AL., *supra* note 6, at 217. Courts often infer that the lack of opposition to a particular technique is synonymous with general acceptance. This is a faulty inference. Lack of opposition could just as well mean that no study has been conducted to verify the reliability of a novel technique. Giannelli, *supra* note 125, at 1243.

the acceptance of the same technique by the forensic scientists who apply it. Research and academic experts who accept DNA typing are no measure of the reliability of this method in the forensic setting.[159] Thus, examining the acceptance of the technique only within the forensic science community will limit the *Frye* inquiry.[160] These material differences between the academic and forensic applications should preclude total reliance upon academic experts in determining the level of general acceptance under *Frye.*

Courts applying the *Frye* doctrine must also be alert to the authorities who are alone in the field and validate their own work, sometimes even in the face of strong scientific criticism.[161] Impartial and knowledgeable expert testimony is the key to an acccurate determination of general acceptance under *Frye.* Courts should ensure that witnesses have no stake in the outcome of the trial, and should reject those whose bias may affect their testimony.[162] Thus, the assumption that general acceptance equals reliablity is the major difficulty with this standard. Moreover, the absence of a uniform approach to *Frye,* coupled with courts' inability to define the relevant scientific community, further complicates the process.

3. Does DNA Typing Satisfy Frye?

A study of the DNA typing cases that utilize the *Frye* standard indicates that criminal trial judges arrive at variety of different answers to this question. Moreover, judges support the same conclusion with different rationales. This section of the Note examines cases from different jurisdictions that purport to follow the *Frye* standard and scrutinizes judges' reasoning when dealing with the problems previously suggested.

People v. Wesley[163] is typical of cases applying *Frye* and finding DNA typing admissible. The defendant's bloodstained clothing was the key DNA evidence in this New York murder trial. The court utilized an altered *Frye* standard opining that mere scientific endorsement of the theory was not sufficient, but that the technique must be "generally accepted as reliable" by the scientific community.[164]

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159. Thompson & Ford, *supra* note 5, at 56–57. The stakes in research and academic applications of DNA typing are clearly not as high as in the forensic setting. The results of DNA typing carried out in research and academic laboratories need not be as reliable as forensic results, because the availability of parental blood samples provide a check for research and academic results. *Id.* These material differences between the applications should preclude total reliance upon the theories of research and academic experts in ascertaining the level of general acceptance under *Frye.* NATIONAL RESEARCH COUNCIL, *supra* note 17, at 52–53.

Indeed, the transfer of the technology from the academic and research laboratories has been one of the major bones of contention in DNA typing litigation. People v. Castro, 545 N.Y.S.2d 985, 990 (Sup. Ct. 1989). Academic experts will not be able to testify as to the reliability of the measures taken by forensic laboratories when faced with interpretation problems unique to forensic laboratories and unknown to clinical laboratories. *Id.* at 993.

160. Thompson & Ford, *supra* note 5, at 56.

161. MOENSSENS ET AL., *supra* note 6, at 7.

162. Thompson & Ford, *supra* note 5, at 59. *See, e.g.,* People v. Kelly, 549 P.2d 1240 (Cal. 1976); People v. Young, 391 N.W.2d 270 (Mich. 1986).

163. 533 N.Y.S.2d 643 (Sup. Ct. 1988).

164. *Wesley,* 533 N.Y.S.2d. at 645 (citing People v. Middleton, 429 N.E.2d 100 (N.Y. 1981)). The *Wesley* court's determination on the areas of expertise required for acceptance has been criticized as being too broad, because it included general approval from scientists who may

The defense attacked the procedures, methodology, and quality control as being insufficient to guarantee reliability and accuracy of the results. The defense also attacked the prosecution's population genetics statistics. The defense argued that the testing laboratory's population studies were an inadequate foundation on which to establish the asserted statistical power of identity under the rules of population genetics.[165] The court, however, rejected these arguments. It held that these issues were not material to a finding of admissibility under *Frye,* but rather were issues going "to the weight of the evidence, a matter for resolution by the trier of facts."[166] The *Wesley* court did address some expert technical and procedural testimony at trial, yet failed to deal with the lack of consensus regarding match calling or interpretation criteria—a fundamental link in the chain of DNA typing.[167]

Wesley then turned to population genetics, the final substantive phase of DNA typing. The court attempted to resolve certain deficiencies in the laboratory's application of the population genetics by applying an ad hoc reduction of the statistical match probability.[168] Rather than discarding the analysis completely, the trial judge in *Wesley* allowed admittedly flawed data to be presented to the jury.[169] It is doubtful that the bench-imposed arbitrary reduction of the accidental match probabilities was of any real benefit to the defendant.[170] Even at these reduced levels, the large numbers undoubtedly had a substantial impact on the jury. The defense was likely unable to counter this

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have been unfamiliar with the adverse conditions of DNA typing. Thompson & Ford, *supra* note 5, at 102–03. The court relied upon an article by Dr. Michael Baird, entitled *Human Population Genetic Studies of Five Hypervariable DNA Loci,* which had not yet undergone peer review, and which was, at the time of the opinion, unpublished. Dr. Baird was an employee of Lifecodes, the testing laboratory. None of the prosecution's experts appeared to have any tangible forensic experience. *Id.* at 103.

165. *Wesley,* 533 N.Y.S.2d at 650.

166. *Id.* The *Wesley* court first reviewed all of the procedures for RFLP analysis. *See supra* notes 37–68 and accompanying text. It found all six of the steps to be generally accepted. *Id.* at 649–50. The court specifically failed to address any issues relating to the interpretation of the autorads and the declaration of matches. Because DNA typing should be regarded as a series of three discrete procedures, the *Wesley* court's wholesale approach is not, and should not, be universally followed. *Compare* People v. Halik, No. VA 00843 (Cal. Sup. Ct. Los Angeles County 1991) discussed *infra* notes 188–201 and accompanying text.

167. Interpretation and match declaration procedures are discussed *supra* at notes 73–79 and accompanying text.

168. The court encountered difficulties trying to compensate for issues of linkage and disequilibrium. *Wesley,* 533 N.Y.S.2d at 658. This reduction was proposed by one of the prosecution's expert witnesses, who thought that such a reduction was necessary in that there were individual genotypes that occurred slightly more frequently than predicted and others which occurred with less frequency. *Id.*

169. *Id.*

170. The court reduced the "mean power of identity for American Blacks from 1 in 1.4 billion, to 1 in 140 million, and for [Caucasians], from 1 in 840 million to 1 in 84 million." *Id.* The expert's reduction factor may have been out of line. Although individual population data bases should be examined carefully for deviations from expected genetic models, the extent to which mathematical compensations should be made to account for these deviations is not known. GENETIC WITNESS, *supra* note 7, at 68. The DNA typing in this case arguably lacked adequate foundation. Although evidence lacking foundation is usually excluded, it was admitted here. Moreover, the court is not qualified to make these adjustments; it should have discarded the entire result.

prejudicial impact.[171] *Wesley* illustrates the inability of the *Frye* standard to evaluate adequately a complicated scientific technique such as DNA typing when the judge fails to examine all of the relevant issues.

In another New York homicide case, *People v. Castro,*[172] the court also utilized the *Frye* rule, but refused to admit the proposed DNA evidence.[173] The trial judge focused on quality assurance issues and population genetics issues with a three-prong test which expanded the inquiry beyond general acceptance and examined the testing laboratory's application of the technique to the specific case.[174] *Castro* required the proponent of the evidence to establish that the DNA typing tests were conducted properly on a case-by-case basis.[175] The court reasoned:

> that given the complexity of the DNA multi-system identification tests and the powerful impact that they may have on a jury, *passing muster under* Frye *alone is insufficient to place this type of evidence before a jury,* without a preliminary, critical examination of the testing procedures performed in a particular case.[176]

The judge held that the testing errors in this case were so profound that a ruling of inadmissibility was necessary as a matter of law.[177] *Castro* illustrates

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171. For a discussion of the difficulties encountered by defendants attempting to attack DNA evidence, see *infra* text accompanying notes 276–84.

172. 545 N.Y.S.2d 985 (Sup. Ct. 1989).

173. *Id.* at 999. The *Castro* court refused to recognize DNA typing as a method that would "revolutionize the disposition of criminal cases" or would "constitute the single greatest advance in the 'search for truth.'" People v. Wesley, 533 N.Y.S.2d 643, 644 (Sup. Ct. 1988).

174. The *Castro* three-part test asked these questions:

> (1) Is there a theory, which is generally accepted in the scientific community, which supports the conclusion that DNA forensic testing can produce reliable results? (2) Are there techniques or experiments that currently exist that are capable of producing reliable results in DNA identification and which are generally accepted in the scientific community? (3) Did the testing laboratory perform the accepted scientific techniques in analyzing the forensic samples in this particular case?

Castro, 545 N.Y.S.2d at 987.

175. *See* Jane E. Hanner, Note, *DNA Fingerprinting: Evidence of the Future,* 79 KY. L.J. 415, 434 (1991).

176. *Castro,* 545 N.Y.S.2d at 987 (emphasis supplied). At least one other court has cited this analysis with approval. "[The] approach, whether it be under Rule 702 or *Frye*, should require the court to satisfy that the evidence meets *all three tests laid out in* Castro." United States v. Two Bulls, 918 F.2d 56, 60 (8th Cir. 1990), *vacated for reh'g en banc,* 925 F.2d 1127 (8th Cir. 1991) (emphasis supplied).

177. The court stated:

> It is noted that issues of fact which arise as a result of the hearing concerning the reliability of any particular test, or the size or ratio of the population frequency, relates to the weight of the evidence and not its admissibility. *However, where the results are so unreliable, as was demonstrated in this case, the results are inadmissible as a matter of law.*

Castro, 545 N.Y.S.2d at 999 (emphasis supplied). *Castro* was particularly concerned with quality control and standards. The court criticized the laboratory for failing to run monomorphic probes, which are helpful in determining the degree of DNA degradation. *See supra* note 43. The court also found that the failure to include gender controls rendered the results unusable. *Id.* at 997. Even though the testing laboratory attempted to rectify this situation by running the controls with another batch, the court found that this did not comport with acceptable laboratory practice. *Id.* Gender controls are part of the controls necessary to test for proper electrophoresis and hybridization results. *See generally supra* note 100.

the potential effectiveness of the *Frye* standard when it is applied to both the theory and the practice of a novel technique.

In *State v. Hummert,*[178] the trial court took a different approach by allowing the state to introduce evidence of a match but precluding the utilization of the population genetics data gathered by the prosecution. The court relied on both the *Frye* standard and the relevancy approach embodied in the *Federal Rules of Evidence.*[179]

The *Hummert* court divided the DNA typing procedure into two parts: the analysis stage and the population genetics stage. It found that the DNA testing, the laboratory protocol, and the proper performance of the tests in these two cases were generally accepted as reliable.[180] The judge, in ruling that DNA typing was generally accepted, relied on transcripts, expert testimony, and judicial opinions from other cases, as well as the testimony in the instant case.[181] Additionally, the trial judge referred to legislative findings.[182] *Hummert* concluded that "there is broad and deep acceptance as reliable the kind of DNA testing performed here which led to the conclusions of 'matches.'"[183]

The court denied the prosecution's motion to use the population genetics data, finding significant disagreement regarding the application of population genetics principles to forensic DNA testing, even among the prosecution's own experts.[184] This disagreement, coupled with trial and appellate court rulings from other jurisdictions, persuaded the court to conclude that "the use of assumptions about general populations [sic] genetic traits ... has not gained

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The results in the *Castro* case indicated two bands whose presence could not be explained; because the testing laboratory omitted readily available experiments with bacterial plasmid probes the court was unable to justify a match by itself and subsequently rejected the validity of the test without the control. *Id.* Having rejected the procedure on quality control issues, the court declined to venture into the acceptability of the population genetics. *Id.* at 998.

178. No. CR 90-03684 (Super. Ct. Maricopa County, Ariz. 1991).

179. *Id.* at 6 (Pretrial Ruling on Admissibility of DNA Testing). The court wrote: "The *Frye* standard of 'general acceptance within the relevant scientific community' is followed in Arizona, so long as the procedure's results meet other relevancy tests." *Id.* at 2. *See generally* State v. Alday, 165 Ariz. 480, 799 P.2d 821 (1990); State *ex rel.* Collins v. Superior Court, 132 Ariz. 180, 644 P.2d 1266 (1982). The relevancy standard is discussed *infra* notes 207–42 and accompanying text.

180. *Hummert,* No. CR 90-03684, slip op. at 4 (Pretrial Ruling on Admissibility of DNA Testing). The *Hummert* court cited the analysis in *United States v. Two Bulls,* which called for an intensive pre-trial hearing to determine: 1) whether DNA testing is generally accepted as reliable; 2) whether the lab's testing protocol is generally accepted as reliable; 3) whether the given test was properly performed; 4) whether the test results are more probative than prejudicial, *and* 5) whether the population statistics-based testimony about probabilities of a random match are more probative than prejudicial. *Id.* at 2–3 (citing *Two Bulls,* 918 F.2d at 61).

181. *Id.* at 3–4.

182. "A judicial finding of acceptance and reliability is buttressed by legislative determinations that DNA typing is reliable and useful for identification purposes in other contexts." *Id.* at 5. The Arizona legislature has recognized DNA testing for paternity suits. ARIZ. REV. STAT. ANN. § 12-847 (1992). This analysis may be criticized in that the implementation of quality control, at least for paternity testing, is simpler to implement than quality control for forensic laboratories. For a discussion of the differences in quality control between forensic and other laboratories, see *supra* note 67 and accompanying text.

183. *Hummert,* No. CR 90-03684, slip op. at 5 (pretrial ruling on admissibility of DNA testing).

184. *Id.* at 7.

general scientific acceptance and has not been proven reliable enough to warrant admission into evidence."[185] Moreover, the court found that the laboratory's gene frequency analysis raised significant risks of juror confusion and unfair prejudice to the defendant, which outweighed any probative value of the evidence.[186] Having concluded that the population genetics testimony was inadmissible, the judge was faced with the dilemma of admitting part of the testing analysis—the preparation and interpretation phases—while rejecting only the statistical analysis, or discarding the whole submission. The judge chose the former alternative, but other Arizona courts have not been so restrained.[187]

People v. Halik[188] provides a strict step-by-step *Frye* analysis of the DNA typing method. In *Halik,* the court applied the California version of the *Frye* rule[189] separately to each step of the DNA typing scheme—the RFLP phase, the interpretation phase, and the population genetics phase. The court required that each step be generally accepted as reliable before the jury could hear any part of the evidence.

The court considered the general acceptance of each portion of the analysis, and ultimately rejected the state's offer of the DNA evidence.[190] The court found that the "RFLP analysis" had gained general acceptance in the applicable field, but it limited this holding only to the steps from extraction to autoradiography.[191] The court asserted that "[m]atching is the keystone in the archway to admissibility,"[192] and examined the level of general acceptance of the testing laboratory's interpretation protocol. It found that the experts were almost evenly split on the acceptance of the testing laboratory's interpretation protocol, thus falling far short of *Frye's* general acceptance requirement.[193] The court disposed of the evidence based upon the interpretation phase of the analytical scheme, and declined to hold on the more controversial population genetics issue.[194]

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185. *Id.* at 10.

186. *Id.*

187. *See, e.g.,* State v. Despain, No. 15589 (Super. Ct. Yuma County, Ariz. 1991). The *Despain* court rejected the entire analysis. It found that the state had failed to prove by a preponderance of the evidence that the population genetics principles, as applied to forensic DNA typing, had been generally accepted by the relevant scientific community. *But see* State v. McComb, No. CR 90-06024 (Super. Ct. Maricopa County, Ariz. 1991) (paralleling the analysis of *Hummert,* admitting in part, and denying in part).

188. No. VA 00843 (Super. Ct. Los Angeles County, Cal. 1991).

189. In addition to *Frye,* California courts apply the rule developed in People v. Kelly, 549 P.2d 1240 (Cal. 1976). *Kelly* involves a two-step process that requires a reliable method and a qualified expert.

190. "[T]he task at hand is not to determine, by the preponderance of the evidence or any other standard of proof, whether the procedures used by the [laboratory] in this case are reliable; the sole issue to be resolved is whether such procedures have gained general acceptance in the relevant scientific community. For purposes of such inquiry, reliability is irrelevant." *Halik,* No. VA 00843, slip op. at 7 (order on FED. R. EVID. 402 Hearing).

191. *Id.* at 16. *See supra* notes 37–68 and accompanying text.

192. *Halik,* No. VA 00843, slip op. at 17.

193. *Id.* at 39.

194. *Id.* at 40 ("The issue whether the relevant scientific community has accepted the methodology used by the FBI to determine statistically the frequency with which a given DNA fragment occurs in the general population is not decided. The powerfully persuasive testimony

If courts consider the discrete phases of DNA typing as a whole, the theory underlying the DNA typing process seems to be generally accepted. However, several issues relating to the specific application of that theory to forensic RFLP analysis and interpretation[195] and population genetics[196] remain in dispute. The *Halik* analysis represents an important step in the direction of resolving these issues because it does not permit deficiencies in one phase to be masked by strong points of the other phases. But other courts, such as *Hummert,* decline to assert themselves and instead "pick and choose" which parts of the DNA typing results the jury should receive.[197]

The propriety of this "pick and choose" approach is dubious in the face of lay public attitudes on DNA analysis. The choice of whether or not to bar admission of the entire result due to invalid population genetics results, which "provide meaning and numerical weight to the DNA techniques,"[198] turns upon the value a lay jury is likely to give DNA typing without population statistics. To assess what many jurors will believe, one need only look to the non-technical media, which has played up DNA typing and techniques as the new super-sleuths and super-doctors of the twentieth century.[199] Lay jurors

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given in support of that protocol ... is beyond the reach of the issues when matching has not passed the test of *Kelly–Frye.*").

195. Certain issues surrounding hybridization and probing of the membranes containing the DNA strands remain unresolved. Scientists generally accept the theory behind the hybridization and probing, but most support comes from the research setting. It is accepted that multiple-reprobing is necessary in order to narrow the probabilities of a random match; however, there is no general acceptance of a standard number of probes that is necessary to adequately reduce this possibility. *See supra* notes 55–62 and accompanying text. Effectiveness of individual probes at seeking out the polymorphic regions necessary for identification of individuals needs further study. Thompson & Ford, *supra* note 5, at 73.

Computerized mathematical compensations lack the necessary foundation for admission because they have been demonstrated to be of questionable scientific value. If correction factors are material to the outcome of the scientific result, courts should be wary of admitting them. KIRBY, *supra* note 4, at 120; Thompson & Ford, *supra* note 5, at 76.

Match calling procedures also lack necessary foundation. *See* Paul Hagerman, *Loading Variability and the Use of Ethidium Bromide: Implications for the Reliability of the FBI's Methodology for Forensic Lab Typing*, Expert's Report at 12, United States v. Yee, 134 F.R.D. 161 (N.D. Ohio 1991) ("[t]here are major uncertainties in the approach taken by the F.B.I. ... which further call into question their ability to either accurately size an individual band against known standards, or to make an accurate comparison between two bands representing DNAs from different sources."); Daniel L. Hartl, Expert's Report at 3, *Yee*, 134 F.R.D. 161 ("[T]he matching criteria employed by the FBI would not be considered as generally accepted and reliable in the scientific community.").

196. The assumption underlying the population genetics portion of DNA testing that humans mate randomly and that the genetic pool is in equilibrium has been flatly denied. *See* GENETIC WITNESS, *supra* note 7, at 68 ("Certain alleles clearly concentrate within specific ethnic groups."). Population genetics procedures and pitfalls are discussed *supra* notes 81–90 and accompanying text.

197. State v. Hummert, No. CR 90-03684 (Super. Ct. Maricopa County, Ariz. 1991) at 14–15. Other cases have followed this line of reasoning. *See* State v. Pennell, 584 A.2d 513 (Del. Super. Ct. 1989); Caldwell v. State, 393 S.E.2d 436 (Ga. 1990); Commonwealth v. Curnin, 565 N.E.2d 440 (Mass. 1991).

198. GENETIC WITNESS, *supra* note 7, at 8.

199. *See, e.g.*, Earl Ubell, *Whodunit? Quick, Check the Genes!*, PARADE March 31, 1991, at 12 ("With the same precision [99.999 percent] scientists can take a spot of blood or semen or a hair root from the scene of a crime and tell you whether those samples match others taken from an accused person."); *The Age of Genes*, U.S. NEWS & WORLD REPORT, November 4, 1991, at 64.

exposed to this media attention may consider DNA typing infallible, giving it more weight than it deserves in a court of law. Where the population genetics have already been injected into the proceedings by the lay media, the jury may automatically consider it a part of the procedure, even though it has not been admitted into evidence. The only way to correct for this deficiency is to discard the entire DNA result upon a showing of non-admissibility of the population genetics.[200]

Halik is perhaps the only case to critically examine the general acceptance of the matching protocol standing alone.[201] Each of the aforementioned cases, except *Wesley,* has dealt with the DNA typing procedure as a series of discrete components, but only to a limited extent. In order for the *Frye* test to be of any protection to the defendant, the courts must broaden the limited extent of these holdings, and, like the *Halik* court, heighten the scrutiny directed at each constituent step. Judges need to avoid the "coattail effect," and prevent their acceptance of the first phase from influencing their findings regarding the other portions of the procedure.

Quality laboratory practice is the final issue to be discussed under *Frye.*[202] General acceptance of the DNA typing procedure as a whole should require that the protocol and rules of DNA quality assurance and quality control also be generally accepted. Without uniform and accepted quality laboratory practice guidelines, the substantative procedures become compromised.[203] General acceptance of the procedures now in place, however, is "the most controversial and unsettled issue," in DNA testing.[204] There are several problem areas in quality laboratory practice. There are no mandatory quality assurance programs, and there is no general consensus for the structure of such a program if one existed.[205] Moreover, programs which train analysts are clearly inadequate.[206] When viewed in this light, the general acceptance of current quality laboratory practice is questionable and once again brings into doubt whether DNA typing can withstand a strict step-by-step *Frye* scrutiny. Thus, if courts were to actively weigh quality laboratory practice equally with other substantive procedures, those courts adopting the *Halik* approach would most likely reject DNA typing where quality laboratory practice was deficient. Other intepretations of the *Frye* rule, however, simply cannot make these distinctions.

Trial courts are not likely to change their approach to *Frye* without a clear mandate from the higher courts. Higher courts, however, are not likely to

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200. "To say that two patterns match, without providing any scientifically valid estimate ... of the frequency with which such matches might occur by chance, is meaningless." NATIONAL RESEARCH COUNCIL, *supra* note 17, at 74.

201. People v. Halik, No. VA 00843 (Super. Ct. Los Angeles County, Cal. 1991) at 19–20 (order on FED. R. EVID. 402 hearing).

202. Issues relating to quality laboratory practice are discussed *supra* notes 91–119 and accompanying text.

203. NATIONAL RESEARCH COUNCIL, *supra* note 17, at 98.

204. GENETIC WITNESS, *supra* note 7, at 10.

205. *See supra* note 106.

206. Analysts are trained primarily through a series of on-the-job apprenticeships and by attending scientific seminars and conferences, because formal academic coursework in forensic science is available at only a few institutions, and internships for undergraduates are not widely available. Many observers decry the current methods of training and resources available as "woefully inadequate." GENETIC WITNESS, *supra* note 7, at 77.

issue such a mandate given the current muddiness of the *Frye* standard and the vagaries of its application. Courts seem unsure whether to direct scrutiny at the whole procedure, or parts of the procedure. Additionally, the credibility of some parts of the procedure shrouds the lack of acceptance of other, less-developed parts, and the outcome depends heavily on the court in which the case is tried. The result is that criminal defendants and prosecutors alike cannot accurately predict the strategies or the outcome in advance. Criminal defendants faced with damaging DNA typing evidence are unlikely to find the relevancy standard any more amenable to their interests, as it provides even less protection from potentially faulty DNA typing results than does *Frye*.

B. Relevancy Under the Federal Rules

1. The Theory Behind Relevancy

The relevancy standard, used in thirty-two states and most of the federal court system,[207] provides that relevant evidence shall always be admissible unless "its probative value is substantially outweighed by the danger of unfair prejudice, confusion of the issues, or misleading the jury."[208] Courts hearing DNA typing cases often employ the relevancy standard.[209]

According to the *Federal Rules*, scientific expert testimony is relevant and probative if it is of some assistance to the trier of fact.[210] Expert testimony is admissible as long as it relies upon the same basis as that relied upon by other experts in that particular field.[211] Expert testimony in a relevancy hearing generally deals with the reliability of the technique that generated the result. Reliability and relevancy are necessarily intertwined because without demonstrable reliability, evidence is not relevant.[212] Judges who lack a scientific background must rely upon expert testimony when assessing the probative value of an evidentiary item.[213]

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207. GENETIC WITNESS, *supra* note 7, at 16. The United States Supreme Court has granted certiorari to review whether FED. R. EVID. 702 displaces or suprecedes the *Frye* standard. *High Court to Decide Admissibility of Scientific Evidence in U.S. Courts*, THE N.Y. TIMES, October 14, 1992, at A9. *See* Daubert v. Merrell Dow Pharmaceuticals, 113 S. Ct. 320 (1992).

208. FED. R. EVID. 403. Federal Rule 401 defines relevant evidence as "evidence having any tendency to make the existence of any fact that is of consequence to the determination of the action more or less probable than it would be without the evidence." FED. R. EVID. 401. *See generally* Beeler & Wiebe, *supra* note 35, at 934; Kenneth R. Kreiling, *Scientific Evidence: Toward Providing the Lay Trier with the Comprehensible and Reliable Evidence Necessary to Meet the Goals of the Rules of Evidence*, 32 ARIZ. L. REV. 915, 924–29 (1990); C. MCCORMICK, EVIDENCE § 203, at 608–10 (3d ed. 1984).

209. *See* United States v. Jakobetz, 747 F. Supp. 250 (D. Vt. 1990), *cert. denied*, 113 S. Ct. 104 (1992); Andrews v. State, 533 So. 2d 841 (Fla. Dist. Ct. App. 1988); United States v. Two Bulls, 918 F.2d 56 (8th Cir. 1990), *vacated for reh'g en banc*; 925 F.2d 1127 (8th Cir. 1991); Kelly v. State, 792 S.W.2d 579 (Tex. Crim. App. 1990).

210. FED. R. EVID. 702 provides that:

> [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, a witness qualified as an expert by knowledge, skill, experience, training, or education may testify thereto in the form of an opinion or otherwise.

211. Beeler & Wiebe, *supra* note 35, at 934–35; *See also* FED. R. EVID. 702.

212. Giannelli, *supra* note 125, at 1235.

213. *Id.* at 1236. *See also* Strong, *supra* note 141.

Unlike the *Frye* standard, which at least requires approval by some unspecified quorum of experts, the *Federal Rules* provide no threshold amount of testimony. A judge, therefore, may make a relevancy and reliability determination based upon the testimony of a single expert,[214] or the trial judge may simply consider "any relevant conclusions supported by a qualified expert witness."[215] The dangers of this are striking. Because the relevancy standard requires a determination that the dangers outweigh the probative value, the judge must rely on expert witnesses to assess both the probative value and the dangers. The fewer the experts relied upon, the less reliable this determination becomes.[216]

Under the relevancy model, all types of evidence are examined in the same manner. Scientific evidence, therefore, is treated the same as other expert testimony, and is usually admitted in the same manner.[217] The *Federal Rules* provide a flexible framework for admitting scientific evidence so that "the rigor of the requisite foundation can be adjusted to suit the nature of the evidence and context in which it is offered."[218] Using this flexibility, the courts have developed a three-step test for relevancy. This test involves ascertaining the probative value of the evidence, identifying the dangers and concerns, and then balancing the probative value of the evidence against the identified dangers.[219]

2. Relevancy Standard Deficiencies

Many observers question the relevancy standard's usefulness as applied to novel scientific techniques.[220] Scientific evidence has the potential to mislead the jury, and may overwhelm them into accepting a novel technique without critical scrutiny. The judge, therefore, must be especially aware of this danger when ruling upon admissibility. The alert judge must rely upon opinions offered by the expert witnesses and issue cautionary instructions about these opinions to the jury. The effectiveness of these instructions, however, is doubtful.[221]

The relevancy model does not reject novel techniques at the outset, but instead allows the jury to weigh the evidence. The model depends upon adversarial trial safeguards and the right to cross-examination as a means of guarding against abuse and confusion.[222] For instance, testimony of the prosecution's expert witness may indicate an infallible method and never

214. Giannelli, *supra* note 125, at 1237.

215. MCCORMICK, *supra* note 208, at 608. Testimony on relevancy and probative value may encompass both the underlying principles and the particular applications of a theory. *Id.*

216. Strong, *supra* note 141, at 22 ("[I]n the case of scientific evidence the court will generally be forced to accept the probative value of the evidence as what a qualified expert testifies it to be."). Because the testing laboratories employ many of the prosecution witnesses in a DNA trial, fairness renders judges unable to determine probative value on their testimony alone. Thus, providing the defendant an adequate expert base becomes critically important.

217. Melson, *supra* note 13, at 197.

218. MCCORMICK, *supra* note 208, at 609.

219. Giannelli, *supra* note 125, at 1235. The standard of proof for this model has been found to be by clear and convincing evidence. United States v. Jakobetz, 747 F. Supp. 250, 255 n.9 (D. Vt. 1990), *cert. denied*, 113 S. Ct. 104 (1992).

220. *See* MOENNSENS, ET AL., *supra* note 6, at 12 (citing workshop recommendations from National Conference on Lawyers and Scientists, 99 F.R.D. 187, 101 F.R.D. 599 (1983)).

221. Giannelli, *supra* note 125, at 1237–38.

222. Beeler & Wiebe, *supra* note 35, at 936.

touch upon the technique applied in the instant case. The *Federal Rules* assume that the defense attorney will expose any flaws in the witness' testimony through cross-examination of a sometimes evasive witness. The jury is expected somehow to gleen the reliability of a technique from the opposing parties' conflicting and often complex expert testimony.[223]

The relevancy model poses further difficulties for the criminal defendant in DNA typing cases. Because Rule 403 requires that the level of prejudice must "substantially" outweigh the probative value of the evidence,[224] the defendant in courts using the relevancy model may be hard pressed to marshall enough evidence in his behalf to tip the scales against admissibility.[225] Furthermore, the weighing process is a matter of judicial discretion, and appellate courts rarely overturn the findings of the trial judge upon review.[226] Thus, the flexibility of the relevancy standard is illusory. Given the infallibility and certainty that is attributed to DNA typing evidence in the public mind, it is unlikely that a criminal defendant derives any real benefit from the *Federal Rules*.

3. DNA Typing and Relevancy

State v. Andrews[227] was the first case to explore DNA typing at the appeals level employing the relevancy standard. In determining admissibility the *Andrews* court looked to a variety of factors, including: the novelty of the scientific technique and its relationship to traditional methods of forensic analysis, the presence of scientific literature about the technique and the non-forensic applications of the technique, and the court's general impressions of the witness' stature and qualifications.[228]

Although the *Andrews* court received testimony from three state's experts, no defense experts testified at trial.[229] Based upon the testimony of these experts, the court opined that the results of DNA testing would be helpful to the jury and thus had probative value.[230] The defense was unable to present any adverse testimony at that time, and as a result, the *Andrews* court did not address any substantive technical issues in its terse opinion.[231] The

223. Giannelli, *supra* note 131, at 195. The susceptibility of jurors to statistical evidence is discussed *infra* at notes 245–69 and accompanying text.

224. FED. R. EVID. 403.

225. The difficulties encountered by defendants in introducing exculpatory testimony against scientific testimony, obtaining experts, and cross-examining opposing experts is discussed *infra* at notes 269–76 and accompanying text.

226. Giannelli, *supra* note 125, at 1239.

227. 533 So. 2d 841 (Fla. Ct. App. 1988). The Florida law of evidence was apparently in a state of flux. The *Andrews* court carefully reviewed the precedents, and determined that *Frye* was not the rule in Florida. Instead, the court embraced relevancy as the "linchpin of admissibility." *Id.* at 846–47.

228. *Id.* at 847 (citing United States v. Downing, 753 F.2d 1224, 1238–39 (3d Cir. 1985)).

229. The testing laboratory employed two of the three witnesses. The third witness based his evaluation of the testing scheme upon a visit he paid to the testing laboratory (Lifecodes), although he never witnessed the actual test. Andrews v. State, 533 So. 2d 841, 847 (Fla. Ct. App. 1988).

230. *Id.* at 849.

231. The court did briefly discuss population genetics and the Hardy–Weinberg equilibrium, but failed to address whether or not the underlying populations were in equilibrium. *Id.* at 850. The court failed to address other issues as well. The dearth of analysis into such

court relied upon the assurances of the state's witnesses that the chances of misidentification were non-existent because errors in technique led to non-results, not wrong results.[232] Further testimony could have indicated sample submission errors, or possible sample switching, but the court apparently did not receive such testimony. Although the court noted that the laboratory used controls in the experiment, these controls were not explored in depth.[233] The court also relied upon the existence of extensive academic writing about DNA testing and cited with approval the extensive use of DNA in clinical non-forensic settings. *Andrews*, then, demonstrates how important adequate defense testimony is in achieving a proper result under the relevancy standard.

Even where defense testimony is available, the relevancy standard still fails to provide a level of protection equal to *Frye*. In *United States v. Jakobetz*,[234] the defendant presented testimony, and the court explored the technical issues in greater depth, but found that the population genetics frequency methods that the FBI used were probably reliable. The court did, however, concede that the protocols "are probably not generally accepted within the population genetic or human population genetic scientific community."[235] Moreover, the FBI's failure to obtain consistent results between the first and second runs of the same data base was left for the jury to weigh, as were several issues regarding population ethnic structuring. The court asserted that these issues would be "comprehensible to most lay people" even though "DNA profiling is particularly capable—in more ways than one—of lulling a jury into slumbering at its post and not rigorously sifting the evidence."[236] Despite these problems, the court admitted the DNA evidence because "the combined ability of cross-examination, opposing expert witnesses, and limiting instructions [are sufficient to] counteract the hazards of DNA profile evidence."[237] Thus, even with the presence of defense testimony, *Jakobetz* further illustrates the shortcomings of the relevancy standard with respect to genetic evidence; concededly untested theories were allowed to reach the jury.

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critical issues as the application of tests conducted in a particular case further indicates the shortcomings of the relevancy standard, particularly when the testimony presented to the judge is one-sided. *See generally* United States v. Yee, 134 F.R.D. 161 (N.D. Ohio 1991); People v. Castro, 545 N.Y.S.2d 985 (Sup. Ct. 1989); United States v. Porter, No. F06277-89 (Super. Ct. D.C. 1991).

232. The *Andrews* court stated:

> The testimony here was that if there was something wrong with the process, it would ordinarily lead to no result being obtained rather than an erroneous result. Further control samples are employed throughout the process which permits errors, if any, to be discovered.

Andrews, 533 So. 2d at 850.

233. The Appeals Court was unlikely to send the case back on remand to explore these issues, because the standard employed in *Andrews* was the familiar "abuse of discretion" standard. *Id.*

234. 747 F. Supp. 250 (D. Vt. 1990), *cert. denied*, 113 S. Ct. 104 (1992).

235. *Id.* at 262 n.24. Such an admission would be fatal in a *Frye* analysis, which requires general acceptance in the relevant scientific community. Frye v. United States, 293 F. 1013, 1014 (D.C. Cir. 1923).

236. *Jakobetz*, 747 F. Supp. at 262.

237. *Id.*

The Eighth Circuit addressed the application of the technique to the particular case when it decided *United States v. Two Bulls.*[238] Utilizing both the *Frye* and the relevancy standard, the *Two Bulls* court adopted *Castro's* three-prong inquiry,[239] and rejected the government's argument that Rule 702's liberal admissibility standard superseded *Frye.* It found instead that both *Frye* and Rule 702 required laying a proper foundation before evidence derived by any novel scientific technique or laboratory procedure could be admitted.[240] The court ultimately held that the DNA typing evidence was admitted in error, because the trial court failed to verify that the FBI laboratory properly performed the testing procedures in this case.[241] Upon remand, the Eighth Circuit required that:

> [t]he 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 performed properly, (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.[242]

Thus, *Two Bulls* represents an important step forward in overcoming the barriers confronted by the criminal defendant attempting to refute potentially prejudicial novel scientific evidence in the relevancy model. Instead of focusing upon the primarily academic issues studied by the *Andrews* court, *Two Bulls* specifically requires a showing that the testing procedure was accurately performed in each specific case.

The *Frye* standard's focus upon issues relating only to the general acceptance of a scientific technique clouds other technical issues, such as the application of the procedure in a particular case, that are crucial to a finding of reliability. Instead, these issues are left for the jury to decide. Likewise, the relevancy standard also foists many technical issues off on the jury, but for an entirely different reason. A pure relevancy approach can get sidetracked on issues like "probative value" and lose sight of possible errors or inadequate quality laboratory practice. Moreover, under the less stringent "helpfulness" and "probativity" test, relevancy allows many inappropriate technical issues to reach the jury. Both *Frye* and relevancy assume that jurors are competent to hear and decide on just about anything that is "probative," and that all shortcomings, if any, will be remedied by the adversarial system. As the succeeding section indicates, this is a faulty assumption.

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238. 918 F.2d 56 (8th Cir. 1990), *vacated for reh'g en banc*, 925 F.2d 1127 (1991) (not reargued due to death of appellant).

239. *See supra* note 174.

240. *Two Bulls*, 918 F.2d at 59–60. The panel stated:

> Because DNA evidence is so new and the resulting prejudice to the defendant is sufficiently great, it is imperative that the court satisfy itself that there exists a sufficient foundational basis as to the overall admissibility of the evidence. This must be done before the government exposes the jury to the laboratory results.

Id. at 60. The court rejected the presumption of jury competence underpinning the relevancy standard, asserting that once the results reached the jury, even if later found to be lacking foundation, the resulting prejudice would be "obvious." *Id.*

241. *Id.* at 61.

242. *Id.*

III. THE FAILURE OF THE ADVERSARY SYSTEM TO PROVIDE DEFENDANTS ADEQUATE OPPORTUNITIES TO CHALLENGE DNA EVIDENCE AT TRIAL

The principal problem with the relevancy standard and the *Frye* rule is that they both assume that the jury is capable of evaluating scientific evidence effectively with the help of expert witnesses. Futhermore, both assume that the adversary system of cross-examination and refutation is sufficient to protect the accused from scientific evidence that is potentially faulty. This section of this Note argues that jurors tend to be overwhelmed by statistical evidence, and it further explores the difficulties the defendant encounters in obtaining access to expert testimony, cross-examining expert witnesses at trial, and presenting contrary evidence at trial.

A. Jurors Tend to Be Overwhelmed by Statistical Evidence

DNA population genetics are typically expressed in terms of "the likelihood of a random match." This result is given in terms of a ratio, such as "one in a million," and is derived from from a "base rate."[243] This number only establishes the probability that the defendant, if innocent, would have a blood type matching the actual perpetrator, and should not be taken as a measurement of the defendant's guilt. In other words, this number serves only to establish the value of the forensic evidence, and should not be used to directly state culpability for the jury.[244]

There are several problems associated with the use of base rate statistics. The data from which the base rates are drawn must be accurate and informative. Jurors must be able to draw valid conclusions from the data by being aware of sampling variability and bias.[245] To alleviate this problem, the jury must have and understand information regarding sampling techniques, population data gathering and sub-population stratification.[246] The jury, then, must be able to draw conclusions about both the reliability of the statistics and their meaning and transform these conclusions into evidence about the particular case before them.[247] Untrained lay jurors, however, may lack the ability to draw the appropriate conclusions.[248]

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243. Thompson, *supra* note 114, at 10. In this case, the base rate is the frequency with which certain alleles occur in the population, or the likelihood with which that allele will be present in a randomly chosen person in the population.

244. *Id.* at 11. The expression of base rates with regards to DNA typing are typically called "indirectly relevant" base rates. "Directly relevant" base rates, sometimes referred to as "naked statistical evidence," in which the target outcome—guilt, culpability, innocence—is a direct function of some statistical frequency. An example would be where the plaintiff is struck by a blue truck with commercial plates, and attempts to prove the identity of the owner of the vehicle by showing that the defendant owns 80% of all the blue trucks with commercial plates in town. This evidence, in and of itself, is typically insufficient to take any case to the jury. *Id.* at 12. *See, e.g.,* Smith v. Rapid Transit, 58 N.E.2d 754 (Mass. 1945).

245. Thompson, *supra* note 114, at 15.

246. *Id.* at 16. The use of the product rule as it relates to the independence of human mating in DNA testing is frequently submitted to the jury for its consideration. *Id.*

247. Laurence R. Tribe, *Trial by Mathematics: Precision and Ritual in the Legal Process,* 84 HARV. L. REV. 1329, 1346 (1971).

248. Thompson, *supra* note 114, at 17.

Jurors tend to read statistical statements and immediately form conclusions about them, although even a slight change in the wording of a statistical statement of probability could result in astonishingly contradictory conclusions.[249] Moreover, jurors may even form conclusions that are opposite the true meaning of the statement.[250] When the proponent of DNA evidence offers the result that the probability of a random match is "one in one million," the confused juror may equate that statement as "there is a 999,999 to one chance that this man is guilty." Even with other traditional and exculpatory evidence available, mathematical evidence may overwhelm all other evidentiary items in the minds of the jury.[251]

Additionally, jurors must carefully evaluate laboratory error rates.[252] Jurors may draw inappropriate conclusions from the presentation of error rate statistics as well. For instance, jurors often believe that the error rate equals the chance of false incrimination.[253] The traditional adversarial system cannot correct this fallacy, because prosecutors seldom question their own experts about error rates, and defense attorneys seldom have enough familiarity with the concept for effective cross-examination. The end result of this is that error rate statistics are rarely presented in criminal trials.[254] Without the availability of valid error rate statistics, it is extremely difficult to attack statistical evidence, such as DNA typing, at trial.

Drawing inappropriate inferences, such as the guilt of the defendant, from base rate statistics is commonly referred to as following the "prosecutor's fallacy."[255] Attorneys must carefully present DNA typing

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249. KIRBY, *supra* note 4, at 149. For instance, the difference between the laboratory's error rate and the likelihood that the prosecution is trying the wrong perpetrator sound very similar and are frequently confused, but are in fact entirely different propositions. NATIONAL RESEARCH COUNCIL, *supra* note 17, at 88. *See* "defense attorney's fallacy" discussed *infra* note 259 and accompanying text.

250. For instance, it must be stressed to jurors that the frequency of an allele is not the probability of an accidental match. Jurors simply may not be able to understand this distinction. Thompson, *supra* note 114, at 19. The probability that the jurors will draw inappropriate conclusions from mathematical evidence has led one eminent commentator to state that such evidence should be presented rarely, if at all. Tribe, *supra* note 247, at 1377.

251. *Id.* at 1360.

252. Thompson, *supra* note 114, at 22. For instance, the proficiency data gathered on crime laboratories in the United States is collected from a large number of laboratories and presented in an aggregate fashion. The poor quality work, it has been argued, is most likely clustered around a few "bad labs," while most laboratories are "good labs" and have very few errors, but suffer overstatement of error rates because of the others. Another factor that needs to be considered is whether the errors obtained were encountered during blind or open proficiency testing. *Id.* at 22. *See supra* note 114.

253. The statement that a laboratory missed two of 50 proficiency samples in a recent test may lead the confused juror to conclude that "there is a 4% chance that this defendant is being wrongly convicted." Thompson, *supra* note 114, at 23. Forensic science proficiency data is commonly reported only in a form that allows one to infer the overall error rate. *Id.*

254. *Id.* Proponents of scientific evidence, for obvious reasons, are unwilling to discuss error rates with the cross-examining attorney. The proponent may make such statements as "this is reliable, and there is no chance of error," and will only state the error rate in terms of hard numbers upon extensive probing by a skilled cross-examiner, who must often have the assistance of another expert. *Id.* at 23–24.

255. Thompson, *supra* note 114, at 25. An example is illustrated *supra* at text accompanying note 251. *See also* State v. Hummert, No. CR 90–03684 (Super. Ct. Maricopa County, Ariz.) at 11, where the court wrote:

evidence, because, by its very nature, DNA evidence may be particularly "lulling" to the lay jury.[256] Recent jury studies provide some support for this assertion.[257] For instance, a juror who has adopted the prosecutor's fallacy, and has determined that the chances of the defendant being guilty are ninety-percent based upon genetic statistical evidence like DNA typing will tenaciously hang on to that numerical figure, even in the presence of other mitigating evidence.[258]

Still other jurors adopt what is called the "defense attorney's fallacy." This is where a juror believes that chances against a match on a rare characteristic are irrelevant and gives them no weight.[259] The Thompson jury studies indicate that one quarter of jurors will believe either of these fallacies.[260] Thompson's overall findings were that lay jurors have even more difficulty detecting fallacious arguments after the case has been orally argued, as opposed to just reviewing the evidence.[261] The studies also indicated that the so-called prosecutor's fallacy was more influential after deliberation, particularly if the defense failed to address the fallacy effectively.[262]

The mock jurors' ability to balance statistical evidence with corresponding error rates in Thompson's simulation study was even more disturbing. In the first phase of the study, researchers presented mock jurors with several items of evidence. Each of the items had varying degrees of probative value and a different accuracy rate. When the jurors evaluated the several items together the jurors were able to accurately rank the evidence items from "strongest" items to "weakest." During the second phase of the study, however, when the jurors were presented with only one item of evidence, (some of them receiving the "stronger" evidence and others receiving "weaker" evidence) all of them assigned the item the same relative probative value as other types of evidence they had previously been able to

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> Thoughtful commentators and recent trial and appellate decisions agree that testimony involving odds such as 1 in a million that the DNA found on the victim could be someone's other than the defendant's *would likely overwhelm a jury and cause them to confuse those odds with the probability of the defendants* [sic] *innocence.*

Id., slip op. at 11 (emphasis supplied).

256. United States v. Jakobetz, 747 F. Supp. 250, 262 (D. Vt. 1990), *cert. denied*, 113 S. Ct. 104 (1992).

257. Thompson, *supra* note 114, at 30. A jury simulation study is conducted by allowing individuals to read summaries of evidence, and then judge the guilt of a hypothetical criminal defendant. *Id.*

258. *Id.* at 30.

259. *Id.* at 31. Take for instance, a murder trial in a community with a population of one million. The defendant is confronted with evidence that tends to indicate a match with a possibility of random match of one in 100,000. The defense attorney will argue, that given these odds, there are still nine other people in the community that could have contributed the questioned genetic profile. This reasoning is not valid where these 10 other people have no connection with the instant case and the defendant does. *Id.* The presence of the defendant's relatives further complicates the issue. Relatives, particularly siblings, share a greater number of alleles, and this must be accounted for when statistics are presented to the jury. NATIONAL RESEARCH COUNCIL, *supra* note 17, at 86–87.

260. Thompson, *supra* note 114, at 31. The power of each of these fallacies was tested in a series of trials. The results of this analysis are presented *id.* at 31–35.

261. *Id.* at 33.

262. *Id.* at 35.

categorize, despite that item's differing accuracy and probative value. This led the experimenters to conclude that jurors "have difficulty evaluating the absolute strength of any single piece of evidence."[263] Thompson's studies also indicated that mock jurors failed to differentiate weak and strong statistical evidence, and were likely to over-value the weak statistical evidence, by allocating the same probative value to all types of statistical evidence—weak and strong.[264]

Thus, the relevancy and *Frye* standards' approach of passing many evidentiary questions on to the jury actually does not adequately protect the defendant.[265] As the *Two Bulls* court pointed out, once the jury hears faulty DNA evidence, the resulting prejudice to the defendant is "obvious."[266] Moreover, even the presentation of error rates is unlikely to dissipate the "mystic infallibility"[267] that DNA typing has in the eyes of the lay jury.

B. Difficulty Cross-Examining Witnesses at Trial

A defendant must rely upon expert witnesses to counter the state's assertions regarding DNA typing.[268] Expert witnesses are critical to establishing relevance at admissibility hearings and at trial for a jury's evaluation of reliability.[269] Expert witnesses are also crucial to assist the defense in establishing an effective cross-examination. The problem is that expert witnesses are expensive; they often wield impressive credentials, have weighty responsibilities outside the courtroom, and their time is valuable. The tab for an expert can reach upwards of $1,000 a day, plus expenses.[270]

The adversary system forces the defendant to rely upon cross-examination of prosecution experts to defend against novel scientific evidence.[271] The defense's effective cross-examination of the prosecution's expert often exposes problems in reliability and veracity of laboratory results. However, few defense attorneys have the expertise to counter DNA typing evidence without the assistance of an expert, and few defendants have the

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263. *Id.* at 37.

264. *Id.* at 38. The control values for these experiments were established by Baye's Theorem, which mathematically demonstrates the effect of a new item of evidence on a previously established likelihood of a target outcome. *See* MCCORMICK, *supra* note 208 § 211, at 659–62.

265. Courts rely upon the adversarial system to alleviate that confusion, but "one is entitled to doubt the efficacy of even the adversary process as a corrective to the jury's natural tendency to be similarly distracted" by mathematical statistics. Tribe, *supra* note 247, at 1363.

266. United States v. Two Bulls, 918 F.2d 56, 60 (8th Cir. 1990), *vacated for reh'g en banc*, 925 F.2d 1127 (1991).

267. Giannelli, *supra* note 131, at 194 (quoting United States v. Addison, 498 F.2d 741, 744 (D.C. Cir. 1974)).

268. Expert witnesses are essential at pre-trial hearings to determine admissibility, and must be retained again for trial, if there is one, to establish and argue issues of weight in front of the jury. "Securing the services of experts to examine evidence, to advise counsel, and to rebut the prosecution's case is probably the single most critical factor in defending a case in which novel scientific evidence is introduced." Giannelli, *supra* note 125, at 1243.

269. *Id.* at 1244; Thompson, *supra* note 114, at 23. The experts that testify at these hearings are not technicians, but are highly qualified, educated, and experienced scientists. Melson, *supra* note 13, at 195.

270. KIRBY, *supra* note 4, at 130.

271. Effective cross-examination is a constitutional right. *See* Davis v. Alaska, 415 U.S. 308 (1974).

resources to hire an expert.[272] Therefore, even for the most skilled attorney, cross-examination of witnesses is simply not an efficient way of exposing deficiencies in scientific technique and reliability.[273]

Effective cross-examination depends also upon adequate discovery and a free-exchange of information prior to trial.[274] Defendants typically have difficulties obtaining the data, autoradiograms, information about the methodology employed, and sometimes even the actual test results.[275] In addition, courts must allow the defendant adequate time to review and assess the discovered material because inadequate review of the data may jeopardize the effectiveness of the defense's cross-examination.

Clearly, the ability of a criminal defendant to conduct an adequate defense at trial hinges upon the ability to cross-examine. The current state of discovery and the unavailability of information crucial to the defendant inhibits the defendant's ability to conduct an adequate defense against this possibly prejudicial evidence.

C. Defendant's Ability to Present Evidence at Trial

Unlike the murder weapon that can be refired, or the drug sample that can be retested, DNA typing presents a special problem for the defendant. Sample remnants are seldom, if ever, available for subsequent analysis.[276] The accused, then, must rely upon the police laboratory testing and argue at admissibility hearings and trial about the value of the evidence. Once the evidence has been admitted, however, the defendant faces special problems. Certain strict interpretations of the Rules of Evidence make it difficult for the defendant to counter issues of weight for the jury determination.

Without the availability of a retest, the defendant is limited to one argument, namely, that the test is inherently unreliable. The defendant may argue that the test is unreliable either due to general inaccuracies in the theory or because of the particular analyst's error.[277] The defendant is even more

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272. MOENSSENS ET AL., *supra* note 6, at 8.

273. Saltzburg, *supra* note 123, at 211.

274. MOENSSENS ET AL., *supra* note 6, at 217. Professor Moenssens argues that the exchange of information needs to be increased. *See* Melson, *supra* note 13, at 208. The *Castro* court also expressed this belief, and outlined explicitly what free exchange of information should be conducted. People v. Castro, 545 N.Y.S.2d 985, 999 (Super. Ct. 1989).

275. Some scientists accuse the FBI of intimidating scientists whose research and testimony could preclude DNA's admissibility in courts. Shannon Brownlee, *Courtroom Genetics,* U.S. NEWS AND WORLD REPORT, January 27, 1992, at 60. A copy of a confidential report prepared by the National Research Council was leaked to the FBI. Unhappy with the findings of the Council, the FBI responded with a critique of the NRC. The NRC was supposed to make its findings absent political considerations, but the FBI ignored this mandate. *Id.* at 61. The FBI has never submitted to an audit or inspection by an outside agency. *Id.* at 61 *See* State v. Moore, No. DC 90–146 at 12 (Dist. Ct. Gallatin County, Mont. 1991) (imposing sanctions on prosecution for inflictions of "needless expenses for having expert witnesses in attendance at the hearing," and "substantial and needless attorney fees and costs" on the defendant); Hill v. State, 535 So. 2d 354 (Fla. Ct. App. 1988).

276. *Castro,* 545 N.Y.S.2d at 993.

277. Edward J. Imwinkelried & Robert G. Scofield, *The Recognition of an Accused's Constitutional Right to Introduce Expert Testimony Attacking the Weight of Prosecution Science Evidence: The Antidote for the Supreme Court's Mistaken Assumption in* California v. Trombetta, 33 ARIZ. L. REV. 59, 62–63 (1991).

disadvantaged in a state where the legislature has mandated acceptance of DNA evidence.[278] In these states, the court may hold that there is a legislative presumption establishing the reliability of the DNA science evidence, which is not reviewable by the courts. The court will then reject a general defense of unreliability as irrelevant on this basis.[279] Still other courts may take judicial notice of DNA testing, thereby denying the defendant any real rebuttal.[280]

Those arguments available to the defendant, notwithstanding judicial notice and legislative mandates, are susceptible to evidentiary objections that may effectively block introduction of helpful testimony. For instance, the defendant may wish to cross-examine the prosecution expert with hypothetical questions, which are based upon errors that might have occurred or conditions that might have been present.[281] The court would most likely disallow this line of questions if there was not at least a minimal showing that such conditions had actually occurred. If the court is particularly strict, the defense will be literally forbidden to present a defense expert's refutory testimony.[282]

Even if some questions have a factual basis, many courts will strike opinions that are too speculative, thus eliminating the questions because they force the expert to draw uncertain conclusions.[283] The trial judge may also strike the response to the hypothetical question by finding that the testimony would confuse the jury and clutter the issues, or, in the alternative, that the testimony would fail to assist the trier of fact.

The defense may also argue that the general unreliability of the technique renders the result in a particular case questionable. The prosecution, however, may counter that the general testimony is not directly relevant to whether or not the police analyst actually committed an error in the instant case. If the jury is forced to draw too many inferences from general information and apply it to the specific test, the general arguments about

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278. *See supra* note 17.

279. Imwinkelried & Scofield, *supra* note 277, at 64. The constitutionality of these statutes is debatable. It is possible that some courts may consider admissibility questions procedural matters, beyond the province of legislative powers. *See, e.g.*, ARIZ. CONST. art. VI, § 5.

280. Imwinkelried & Scofield, *supra* note 277, at 65.

281. A typical hypothetical question might be, "What would happen if the sample were contaminated with animal urine prior to testing?" The prosecution could probably get a sustained objection to the question if defense counsel is unable to show that the sample actually was or might have been contaminated. Likewise, the defendant would be precluded from asking a question such as "What would have happened if the ethidium bromide stain had been applied prior to hybridization?" (Ethidium bromide is a stain commonly applied to the gels after electrophoresis, allowing the analyst to verify the proper migration of the bands under ultra violet light. Application of the stain prior to electrophoresis may cause band shifting, and distortion of the results. *See* KIRBY, *supra* note 4, at 96–98; NATIONAL RESEARCH COUNCIL, *supra* note 17, at 57.)

282. Imwinkelried & Scofield, *supra* note 277, at 68.

283. *Id.* at 69. *See* FED. R. EVID. 403 which provides that relevant evidence "may be excluded if ... substantially outweighed by the danger of unfair prejudice, confusion of the issues, or misleading the jury...." *See also* FED. R. EVID. 702, which provides that any scientific, technical or specialized knowledge will be admitted as long as it "will assist the trier of fact." For instance if, using proficiency test error rates as a foundation, the attorney asks the testifying expert to draw a conclusion as to the likelihood of error, the prosecution may object on the grounds that the proficiency tests are extraneous evidence that would confuse the jury.

reliability will lose their probative force. This creates the distinct possibility that the judge may accept an argument under Rule 403 that the dangers of admitting the testimony outweigh the limited probative value.[284]

The defendant confronted by DNA typing evidence must submit to these rules. The defendant cannot retest the evidence and must rely upon hypothetical inquiries into what might have been, and what is known about the technique generally. The defendant, then, is at the mercy of the judge and the evidentiary rules when it comes to conducting an adequate defense at trial. In addition, defendants are still vulnerable to lay jurors who may be persuaded by highly technical evidence, and turn a deaf ear to voices that might persuade them otherwise. Yet, as the *Two Bulls* court noted, all of these pitfalls could be avoided if the courts would act to *completely* assure the reliability of DNA typing evidence prior to any trial.

IV. CONCLUSION

The approach that the courts take in dealing with DNA typing evidence is critically important to the criminal defendant. In order for the criminal defendant to realize any benefit from the conservative features claimed to be inherent in the *Frye* standard, that standard, where it is used, must be applied critically to each of the four discrete phases of the typing procedure. More courts should follow the *Halik* approach, which is an important step toward refining the *Frye* standard.[285]

Those courts that apply the relevancy standard need to keep in mind the failures of the adversary system in counteracting any deficiencies in the underlying theory. The inability of the criminal defendant to cross-examine in the face of a strict interpretation of the rules of evidence and the failures of lay juries to adequately consider the impact of technical and personnel errors on the application of the theory to the case are just a few of the failures of the adversary system. The trial judge needs to address these issues prior to trial. Utilization of the balancing test prior to trial is absolutely essential.[286] Furthermore, the requirement that the defendant, in order to preclude admission, must "substantially" outweigh the probative value of the evidence with a showing of prejudice should be scrapped in favor of a simple balancing test in the case of DNA typing evidence and its progeny. Relevancy standard jurisdictions should follow the lead of the *Two Bulls* court,[287] and conclude pre-trial, as a matter of law, that the DNA evidence as submitted is either reliable in its entirety or not at all.

Moreover, during the pre-trial admissibility hearing, the trial judge should strongly consider taking advantage of the provisions of Rule 706, which provides for the appointment of impartial court experts.[288] This may include

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284. Imwinkelried & Scofield, *supra* note 277, at 70–71. The prosecution may successfully argue that the testimony is confusing or too time consuming. *Id.* at 71–72.

285. *See supra* notes 188–201 and accompanying text.

286. Saltzburg, *supra* note 123, at 217.

287. United States v. Two Bulls, 918 F.2d 56, 61 (8th Cir. 1990), *vacated for reh'g en banc*, 925 F.2d 1127 (1991).

288. FED. R. EVID. 706 provides in part that "[t]he court may appoint any expert witnesses agreed upon by the parties, and may appoint expert witnesses of its own selection."

appointing an independent pool of experts to evaluate the theory, the technique, and the application of the theory and technique to the specific case. Under this approach, the evaluation would be organized and methodical, rather than haphazard and spotty.[289]

Additionally, courts need to make better discovery available to defendants. Testing laboratories should be required to disclose all relevant materials, as laid out in *Castro,* so that the defense may establish an adequate case. Furthermore, the court needs to be cognizant of evidence preservation; where it is apparent that sufficient evidence was available for a re-test but was somehow "lost" by the authorities, the court may be justified in raising a judicial eyebrow and conducting further inquiry.

It is not the conclusion of this Note that DNA typing evidence should never be admitted in criminal trials. The theory behind the technique is sound, but the vagaries of error-prone humans applying the technique to forensic casework render the testing unreliable in some cases. The current evidentiary standards are inadequate to ferret out improperly performed analytical work at trial, and reliance on the jury to evaluate these issues is not a sound practice. Only by adopting the valid reasoning of *Castro, Halik,* and *Two Bulls* will courts be able to claim that they have taken a substantial stride towards reliable scientific truth in action.

This rule was invoked in United States v. Yee, 134 F.R.D. 161 (N.D. Ohio 1991), where the court utilized the services of a court-appointed expert.

289. Giannelli, *supra* note 125, at 1232.