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The Use of DNA Typing in Criminal Prosecutions: A Flawless Partnership of Law and Science?

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NOTES

THE USE OF DNA TYPING IN CRIMINAL PROSECUTIONS: A FLAWLESS PARTNERSHIP OF LAW AND SCIENCE?

Consensus is a fragile circumstance in many of the professions whose members are called on to serve as experts. It often is a fleeting condition, and on some issues . . . it is difficult even to reach a consensus on whether the quest for general acceptance has been reached. While we might be justified in applauding the quest for general acceptance to help reduce uncertainty in our decisionmaking, we must never forget that what is generally accepted today might not be generally accepted tomorrow.

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The power of scientific evidence can be used to proper advantage only if it is evaluated with sufficient scientific literacy. If our law schools fail to address that subject, judges and attorneys—either individually or collectively through their professional associations—should take it upon themselves to understand the rudiments of scientific method and the reasons why general acceptance on scientific questions can be difficult to attain. That is the least we can ask.[1]

I. INTRODUCTION

Ms. X is found stabbed to death in her home, a victim of rape and murder. Both blood and semen samples are taken from her body. Suspect D is arrested a year later. In an evidentiary hearing pursuant to a motion to extract blood samples from D, the admissibility of the results of a DNA typing test to be performed on those samples is determined. Various molecular biologists, geneticists, and population geneticists testify about the test's reliability and general acceptance. The experts state that while the forensic application of this test is of recent origin (1987), the underlying technology has been used in many fields for the past ten to fifteen years. Their testimony reveals that there are no scientific publications refuting the validity and accuracy of the underlying theory or the several test procedures, there is absolutely no chance the test would produce a false positive result, and that the test has been admitted in nearly every court in which it was sought to be introduced.[2] Additionally, the experts testify

1. Thomas, *Some Observations By a Scientist*, 115 F.R.D. 79, 142 (1986) (Symposium on Proposed Rules for Admission of Scientific Evidence).

2. See *infra* note 152 for a discussion of the few instances where DNA evidence was

that there are extensive laboratory protocols and quality control measures, and that there have been sufficient population studies to accurately calculate the frequency with which a particular DNA type appears in the population. The judge rules the test admissible and grants the order to take the blood sample from D. The semen sample from Ms. X and the blood sample from D are tested and found to match. Evidence is admitted in the trial to the effect that there is only one chance in 840 million that another male with the same ethnic background as D could have produced the same semen samples. D is subsequently convicted.

While the above scenario is a hypothetical, it is based upon several actual cases that have been tried within the past three years in the United States.[3] The scenario attempts to depict not only the enormous impact DNA evidence may have in criminal proceedings, but also the difficulty a defendant may have in challenging its admissibility. The use of "DNA typing,"[4] otherwise known as "DNA Fingerprinting,"[5] "DNA-Print

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determined to be inadmissable, or where its admission was limited by the court. These cases uphold the general admissability of the technology underlying DNA typing on the basis that it is generally reliable and accepted in the scientific community. However, serious irregularities in the performance of the test or interpretations of the results caused concern about its reliability with respect to the specific sample test in question.

3. See *infra* notes 152 & 156 for a discussion of the cases involving DNA typing.

4. "DNA typing" is the term hereinafter used to refer to the general scientific technique described *infra* notes 72-140 and accompanying text. The term's original source is uncertain, but it is the terminology used in Thompson & Ford, *DNA Typing*, TRIAL, Sept. 1988, at 56. All other terms mentioned herein, three of which are patented, are company- or organization-specific terms. *See infra* notes 5-8. The use of the term DNA typing is therefore somewhat neutral in the sense that it is unrelated to a specific entity.

5. "DNA Fingerprinting" is a patented term used by Cellmark Diagnostics (Cellmark), a division of ICI Americas, Inc., formed in 1986. ICI Americas, Inc. is the United States operating subsidiary of Imperial Chemical Industries, PLC, a Britain-based multinational chemical and pharmaceutical company. Cellmark is based in Germantown, Maryland, and Abington, England. Cellmark uses technology discovered by Professor Alec Jeffreys of the University of Leicester, England, while he was a Lister Institute Fellow. Professor Jeffreys coined the term DNA Fingerprinting. The Lister Institute of Preventative Medicine owns the rights to the technology, and Cellmark has the exclusive worldwide license to market the technique. CELLMARK DIAGNOSTICS, DNA FINGERPRINTING: THE ULTIMATE IDENTIFICATION TEST 2 (1988) (promotional literature) [hereinafter CELLMARK DIAGNOSTICS LITERATURE]. Cellmark has a license from the state of Maryland to perform testing in immunohematology and molecular biology and a federal license under the Clinical Laboratory Improvement Amendments of 1988, 42 U.S.C.A. § 263(a) (1989). Review of DNA Fingerprinting and Its Potential Uses in Civil and Criminal Cases: Hearing Before N.Y. State Assembly Standing Comm. on Codes, Assembly Standing Comm. on Judiciary, Special Joint Project to Investigate the Application of DNA Fingerprinting (Oct. 5, 1988) [hereinafter Hearing] (all statements from this hearing are unpublished and are on file with *New York Law School Law Review*). DNA Fingerprinting became available in the United States on Oct. 1, 1987. Some commentators on DNA typing express reservations about using the term "DNA Fingerprinting," believing that it connotes, incorrectly, an association with conventional fingerprinting. *See* Burk, *DNA Fingerprinting: Possibilities and Pitfalls of a New Technique*, 1988 JURIMETRICS J. 455, 468 ("Even the name

Identification,"[6] "Polymerase Chain Reaction,"[7] or "DNA Profiling,"[8] is a recent phenomenon in criminal prosecutions across the country.[9] DNA typing is a very complicated, highly technical scientific procedure for "matching" the deoxyribonucleic acid (DNA) from a biological substance present at a crime scene or on crime-related material to the DNA present in certain biological substances from the body of the presumed perpetrator.[10] The power of this new technology lies in its purported capacity to associate with unprecedented certainty two or more biological substances.[11] If a "match"

'fingerprinting' may create unsubstantiated beliefs and expectations in the minds of judges and jurors.").

6. "DNA-Print" Identification Test is a patented term used by Lifecodes Corporation (Lifecodes), a division of Quantum Chemical Corporation, formed in 1982. Lifecodes is based in Valhalla, New York, and is a licensed clinical laboratory in the state of New York. This test was first offered for forensic purposes in 1987. LIFECODES CORPORATION, BACKGROUND INFORMATION: DNA-PRINT IDENTIFICATION TEST (1986) (promotional literature) [hereinafter LIFECODES BACKGROUND INFORMATION].

7. "Polymerase Chain Reaction" (PCR), also referred to as "DNA Amplification," is the term used by Cetus Corporation (Cetus) of Emeryville, California, and is licensed to Forensic Science Associates. CETUS CORPORATION, 1988 ANNUAL REPORT. While DNA Fingerprinting and DNA-Print are technologically similar, PCR involves a novel technique that is generally not as accurate as the tests offered by Lifecodes and Cellmark. As of October 22, 1988, the PCR test had not yet been used in criminal trials, but had been used in about 40 criminal investigations. Thompson & Ford, *DNA Typing: Acceptance and Weight of the New Genetic Identification Tests*, 75 VA. L. REV. 45, 50 (1989).

8. "DNA Profiling" is the term used by the Federal Bureau of Investigation (FBI), which has extensively researched the forensic application of DNA technology. The FBI is presently establishing its own testing laboratory using the Cellmark DNA Fingerprinting technique. Hearing, *supra* note 5 (statement of John Hicks, Deputy Assistant Director, Laboratory Division, FBI). The FBI worked closely with Lifecodes, Cellmark, and smaller biotechnology companies in developing its own test. The probes it uses "[are] a blend, or panel, of four different probes, drawing on the techniques" of the other companies. Watson, *FBI Adopts DNA Test At Pioneer's Expense*, Legal Times, Mar. 27, 1989, at 12, col. 4. The FBI Laboratory, as of June 12, 1989, has received over 220 samples from both its own investigations and from police departments around the country since it made its laboratory available to other police departments in January, 1989. Of the first 80 cases, 50 produced a match, 20 exculpated the suspect, and the remaining 10 were inconclusive. Malcolm, *FBI Opens Door for Wider DNA Testing*, Chi. Daily L. Bull., June 12, 1989, at 14, col. 4.

> The FBI now accepts specimens for DNA profiling only in violent personal crimes with a specific suspect, or serial rapes or child molestation without a suspect. To promote the technology's use, the agency is training 60 local technicians a year to help establish local DNA profiling labs, which can cost over $100,000. The agency does not charge police departments for the test, which it says costs about $30.

Id. at 14, col. 6. For further information on FBI initiatives, see Sessions, *Federal Bureau of Investigation*, J. FORENSIC SCI., Sept. 1989, at 1051.

9. *See infra* notes 151-52 and accompanying text.

10. *See infra* note 18.

11. It has been asserted that DNA typing is not actually a "new" technology, but

between the two substances is obtained from the test, the power of identification (the chances that two unrelated individuals will have the same DNA typing) has been asserted to be, in certain contexts, 1 in 84 million,[12] 1 in 140 million,[13] 1 in 840 million,[14] and even as high as 1 in 1 trillion (the world's population is only approximately 5 billion).[15] In addition to its use in criminal prosecutions, DNA typing may also prove to be a revolutionary criminal investigatory tool. Several states and the FBI are currently establishing DNA typing facilities.[16] Additionally, some states and the FBI

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rather a new application of a technology that has existed since the early 1970s. Experts have testified that the technology has been used in the investigation of human genetics, in medical diagnostic testing, in agricultural research, and in environmental research. Hearing, *supra* note 5 (statement of John Hicks, Deputy Assistant Director, Laboratory Division, FBI); *see also* People v. Wesley, 140 Misc. 2d 306, 319, 533 N.Y.S.2d 643, 652 (County Ct. 1988) (citing testimony by Dr. Richard I. Roberts, Assistant Director for Research, Cold Spring Harbor Laboratory, New York, that DNA Fingerprinting entailed no new scientific principles); Hearing, *supra* note 5:

> The procedure is based upon well established techniques in common use by hundreds of molecular biology laboratories in both [sic] industrial, hospital and university settings throughout the United States and the rest of the world. . . . The fundamental techniques are not new. The application of the technology to identification testing is new.

Id. (statement of Daniel D. Garner, Ph.D., Director of Laboratory Operations, Cellmark Diagnostics). The breakthrough or "new technology" has been in the application of DNA typing since 1987 to forensic investigations and evidence.

12. *Wesley*, 140 Misc. 2d at 332, 533 N.Y.S.2d at 659. Lifecodes, relying upon its own population genetics study, claimed a mean power of identity for its identification test of 1 in 840 million for American whites. *Id.* Judge Harris, who presided over the evidentiary hearing, independently reduced this percentage by a factor of 10 to 1 in 84 million to compensate for variances in the frequency of certain genotypes established by other testimony. *Id.* at 332 n.26, 533 N.Y.S.2d at 659 n.26.

13. *Id.* at 332, 533 N.Y.S.2d at 659. Again basing its opinion upon a population genetics study, Lifecodes claimed a mean power of identity for its identification test of 1 in 1.4 billion for American blacks. *Id.* At the evidentiary hearing, Judge Harris independently reduced this estimate to 1 in 140 million to compensate for variances in the frequency of certain genotypes. *Id.* at 332 n.26, 533 N.Y.S.2d at 659 n.26.

14. Andrews v. State, 533 So. 2d 841, 843 (Fla. Dist. Ct. App. 1988). The *Andrews* court did not question the statistical probability estimate where

> Lifecodes testified to a match between DNA in appellant's blood and the DNA from the vaginal swab, stating that the percentage of the population which would have the DNA bands indicated by the samples would be 0.0000012%. In other words, the chance that the DNA strands found in appellant's blood would be duplicated in some other person's cells was 1 in 839,914,540.

Id.

15. Stein, *Genetic Fingerprints: A Boon to Law Enforcement or a Rights Violation?*, PA. L.J. REP., May 2, 1988, at 19 ("Cellmark claims there is a 1 in a trillion chance that two people would share the same genetic fingerprint its technique can produce."). Many commentators, however, believe these statistics are highly exaggerated. *See generally* Thompson & Ford, *supra* note 4; Burk, *supra* note 5.

16. Lifecodes offers a test kit to help state or local authorities update their laboratories

are collecting biological samples from convicted felons for future analysis and incorporation into a DNA database similar to that established for conventional fingerprints.[17]

Although DNA typing has tremendous potential in criminal investigations and prosecutions,[18] there are concerns regarding its accuracy and validity

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to incorporate DNA typing capabilities. For example, Lifecodes provided Virginia with a one-year technology transfer program including procedures and protocols, training, supplies, and continued technical assistance. Hearing, *supra* note 5 (statement of Dr. Paul Ferrara, Director of the Bureau of Forensic Science, Virginia). California, Colorado, New York, and Florida are also preparing to set up their own labs with DNA typing capabilities; at this point, however, it is uncertain which technique will be chosen. *See* Malcolm, *supra* note 8, at 1, col. 3; Shapiro, *Dangers of DNA: It Ain't Just Fingerprints*, N.Y.L.J., Jan. 23, 1990, at 1, col. 1. "Legislation introduced in Sacramento would provide $3 million to establish a network of four regional genetic fingerprinting facilities to be operated by the state Bureau of Forensic Services. The Los Angeles City Council has authorized the police department to send a serologist through an FBI course and to set aside space for genetics work at its new forensics lab." Thompson, *DNA Wins in Court: Anticipating an Age of Genetic Fingerprinting, Police Are Planning Their Own High-Tech Labs*, CAL. LAW., Oct. 1989, at 36. See *infra* note 35 for a discussion of New York's legislative response to DNA Typing. See *supra* note 8 for information on the FBI's DNA typing capabilities.

17. With a view to establishing a DNA database in the near future like the fingerprint databases already in existence, California enacted a law in 1983 requiring all convicted sex offenders to provide blood and saliva specimens at the time of their release from prison. CAL. PENAL CODE § 290.2 (West 1989). More than 4,200 samples already have already been collected. Michaud, *DNA Detectives*, N.Y. Times, Nov. 6, 1988, § 6 (Magazine), at 73. Colorado also requires that persons convicted of sex offenses submit samples for DNA typing before they are released from prison. Malcolm, *supra* note 8, at 14, col. 6. Minnesota also requires convicted sex offenders to submit samples for DNA typing before they are released from incarceration. State V. Schwartz, 447 N.W.2d 422 (Minn. 1989). Illinois, Pennsylvania, Virginia, and Washington are considering similar legislation. Hearing, *supra* note 5 (statement of John Hicks, Deputy Assistant Director, Laboratory Division, FBI). New York State is expected to introduce similar legislation soon and is also considering state funding for DNA testing facilities in state crime laboratories. *DNA "Fingerprinting" Becomes Law Enforcement Tool*, The Rep. Dispatch (White Plains, N.Y.), Feb. 28, 1989, at A14, col. 1; *see infra* note 35. King County, Washington, passed an ordinance on March 28, 1988, requiring all convicted sex offenders to submit to DNA testing. KING COUNTY, WASH., ORDINANCE 8453 (Mar. 28, 1988). In addition, the FBI has designed a computer to read and interpret the results of the DNA typing test for a future database, and other private companies are developing similar computer capabilities. Hearing, *supra* note 5 (statement of John Hicks, *supra*).

18. Since DNA typing has the capacity to analyze both cellular (blood, semen, and tissue) and, less frequently, noncellular (saliva, urine, and sweat) biological substances, one commentator pointed out that "a discarded cigarette butt, shoes, a handkerchief, a wad of gum, or even the inner part of a hat or watchband could yield DNA evidence to solve a crime." Michaud, *supra* note 17, at 72. This ability, however, is only possible with the PCR technique (allele-specific probes discussed *infra* notes 127-40 and accompanying text) which is currently the least reliable and therefore the least used technique. Thompson & Ford, *supra* note 7, at 77. RFLP analysis (discussed *infra* notes 72-126 and accompanying text) would not normally be able to produce a DNA print on saliva, feces, urine, or sweat

in light of its very recent debut in forensic science.[19] There is no dispute that every person except identical twins has a unique DNA "blueprint" much like unique fingerprints; the technology is based on this accepted theory.[20] The technology, however, does not evaluate DNA sequences, and thus, does not evaluate those characteristics that make each one of us individual — for example, hair color, height, eye color, and so forth. Instead, it analyzes the behavior and physical characteristics of groups of identical DNA molecules that scientists have recently discovered are highly variable among individuals. Simply put, those DNA samples that behave exactly the same when subject to specific, highly technical scientific procedures are theorized to belong to the same person.[21] The questions and uncertainties raised by the new technology mainly focus not on the underlying theory, or even the several steps in the process, but rather on the methodology for analyzing the factual data derived from the process as applied to a particular defendant.[22]

The legal implications of DNA typing, including evidentiary and constitutional issues, as well as the practical implications, such as the adversarial function of the legal process and legislative regulatory initiatives,

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because these substances usually do not contain enough DNA for that type of analysis. Comment, *Admit It! DNA Fingerprinting Is Reliable*, 26 HOUS. L. REV. 677, 679 n.21 (1989). RFLP analysis needs a bloodstain the size of a quarter, or a semen stain the size of a dime to produce a DNA print. Other nucleated substances also have minimum threshold size requirements for RFLP analysis. Olivas, *DNA: The Eyewitness of the Future*, COLO. LAW., July 1989, at 1333.

19. *See* Thompson & Ford, *supra* note 7; Olivas, *supra* note 18; *Judge Rules DNA Test Inadmissible; Urges Appeals*, Chi. Daily L. Bull., Aug. 15, 1989, at 1, col. 2 [hereinafter *DNA Test Inadmissible*]; *DNA Evidence Can Be Flawed, Researcher Says*, Chi. Daily L. Bull., June 14, 1989, at 1, col. 5; Cooper, *DNA Case Is Before a State High Court*, Nat'l L.J., July 3, 1989, at 14, col. 1; Sherman, *Lawyers Attacking Test's Reliability*, Nat'l L.J., July 3, 1989, at 14, col. 1; Anderson, *DNA Evidence Questioned*, A.B.A. J., Oct. 1989, at 18; Anderson, *Court Bars DNA Tests in Murder Case*, N.Y.L.J., Aug. 15, 1986, at 1, col. 3; Kolata, *Some Scientists Doubt the Value of Genetic Fingerprint Evidence*, N.Y. Times, Jan. 29, 1990, at A1, col. 1; Spencer, *Panel Urges DNA Test Standards, Designated Labs Legal Advisory Boards Suggested in Report*, N.Y.L.J., Sept. 7, 1989, at 1, col. 3; Wise, *Experts Debate DNA Testing in Criminal Cases*, N.Y.L.J., Oct. 19, 1989, at 1, col. 3; Thompson & Ford, *supra* note 4, at 56; Moss, *DNA — The New Fingerprints*, A.B.A. J., May 1986, at 66; Greenwood & White, *DNA* Fingerprinting and the Law, 51 MOD. L. REV. 145 (Great Britain, 1988); Sensabaugh, *Forensic Biology — Is Recombinant DNA Technology in its Future?*, 31 J. FORENSIC SCI. 393 (1986); Burk, *supra* note 5; Thompson, *DNA's Troubled Debut*, CAL. LAW., June 1988, at 36; *By Their DNA, So Shall Ye Know Them*, CAL. LAW., Feb. 1987, at 8; 1 [Current Reports] CRIM. PRAC. MANUAL (BNA) 19 (Sept. 23, 1987).

Two cases have rejected DNA typing because of its inaccuracy. *See* People v. Castro, 545 N.Y.S.2d 985 (Sup. Ct. 1989); State v. Pennell, No. IN-88-12-0051 (Del. Super. Ct. Sept. 25, 1989).

20. *See* People v. Wesley, 140 Misc. 2d 306, 306-08, 315 n.7, 533 N.Y.S.2d 643, 644, 649 n.7 (County Ct. 1988).

21. See *infra* notes 72-140 and accompanying text for a more in-depth discussion of the technological process.

22. *See supra* note 19 and accompanying text.

integrally hinge upon the validity, accuracy, and scope of the technique. A more than cursory understanding of DNA typing is essential to sufficiently canvass these legal and practical implications. The theories and applications of DNA typing require an understanding and integration of diverse scientific disciplines, including biochemistry, molecular biology, genetics, population genetics, forensic science,[23] of some mathematical knowledge of statistics and population genetics, as well as knowledge of laboratory procedures, protocol, and quality control measures.[24] Part II will present the technological and scientific aspects of DNA typing.

A particularly controversial area in terms of novel scientific evidence, such as DNA typing, is the standard by which the courts admit that evidence. A majority of courts still adhere to the *Frye* standard developed more than fifty years ago.[25] Other courts, influenced primarily by a perceived deficiency in the *Frye* standard as our society moves steadfastedly into the age of technology, and the adoption of the Federal Rules of Evidence, have recently embraced the relevancy approach.[26] In some cases, courts either are not sure of the particular standard adopted in their

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23. In the evidentiary hearing for *Wesley*, conducted over a six-month period prior to the trial, Judge Harris applied the standard for admitting scientific evidence developed in Frye v. United States, 239 F. 1013 (D.C. Cir. 1923), and determined that the scientific fields to which DNA typing belonged were molecular biology, genetics, and population genetics. *Wesley*, 140 Misc. 2d at 309, 533 N.Y.S.2d at 645. Other commentators suggest that biochemistry and forensic science are also pertinent to the determination of "relevant scientific community." *See* Burk, *supra* note 5, at 468.

24. It should be pointed out that DNA typing is premised largely upon theories and hypotheses. For instance, it cannot be empirically proved that everyone has a unique DNA configuration; that would require a test on all those living and dead. The supposition that everyone has a unique DNA, therefore, is based on a statistical probability, albeit a very significant one. As a result, DNA typing relies not only on complicated scientific knowledge, but also upon statistical and mathematical computations referred to as population genetics. Some observers have expressed concern that scientific and mathematical ignorance among the population, as manifested in lay jurors and underfunded public defense counsel, presents a difficult practical problem in the administration of justice when scientific evidence is at issue. This author has spent much time and effort attempting to understand the technique — the complexity of which makes one wonder when a jury deliberates only two hours and comes back with a conviction in a case where DNA typing was the primary evidence. *See* Hill v. State, 535 So. 2d 354 (Fla. Dist. Ct. App. 1988), *discussed in* Moss, *supra* note 19, at 68. A similar concern has led some courts to "express fear that scientific or expert testimony presents a substantial danger of creating undue prejudice, confusing the issues, or misleading the jury because of its 'aura of special reliability and trustworthiness.'" Note, *The Frye Doctrine and Relevancy Approach Controversy: An Empirical Evaluation*, 74 GEO. L.J. 1769, 1774 n.26 (1986) (citing United States v. Amaral, 448 F.2d 1148, 1152 (9th Cir. 1973)). Additionally, in one criminal case in which DNA typing evidence was admitted in Queens, New York, one juror commented to a reporter after the trial that "[t]he DNA was kind of a sealer on the thing. You can't really argue with science." *Man Convicted of Rape on DNA Evidence*, N.Y. Times, Oct. 20, 1988, at B16, col. 2.

25. *See infra* notes 180-206 and accompanying text.

26. *See infra* notes 207-26 and accompanying text.

jurisdiction,[27] creating diverse interpretive language,[28] or ignore the test completely.[29] Part III will briefly examine each approach and the difficulties presented by DNA typing evidence.

Given the concerns raised by DNA typing with respect to its validity and reliability, as well as the inherent problems presented by the standards for admissibility of novel scientific evidence, the constitutional framework necessary to protect the interests of defendants confronted with this type of evidence becomes even more important. Two cases admitting DNA typing already have led to the death sentence.[30] Part IV will analyze the constitutional implications of extracting biological samples from the defendant to perform DNA typing,[31] the possible impingement on the defendant's privacy interests,[32] the fifth amendment guarantee against self-incrimination,[33] and the defendant's right to expert witnesses and independent testing.[34] The constitutional issues primarily stem from the difficulties in applying evidentiary standards for the admissibility of novel scientific evidence to assure reliability, and the effect those difficulties may have on the defendant's right to a fair trial. The concerns are based on several factors: a belief that there has been insufficient validation studies and inadequate peer review, a belief that there are inadequate challenges to the new techniques due to a scarcity of "disinterested" experts and the inadequacy of the adversarial process to evaluate properly the implications and subtleties of the scientific technology, and the movement by a few states to embrace the technology without sufficient consideration as to authoritative quality control measures, protocol procedures, licensing and/or accreditation provisions for laboratories, or adequate independent legislative evaluations.[35]

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27. *See infra* note 207.

28. *Id.*

29. *Id.*

30. *See* State v. Jones, No. 87-1695-CF-M (Putnam County, Fla. Mar. 1988) (in the first capital case using DNA typing, the defendant was convicted of murder, robbery, and sexual assault and received the death sentence) (information supplied by Cellmark); Spencer v. Commonwealth, 238 Va. 563, 385 S.E.2d 850 (1989), *cert. denied*, 110 S. Ct. 759 (1990) (DNA Fingerprinting evidence admitted after a *Frye* hearing; defendant convicted of multiple rape/murders and sentenced to death).

31. *See infra* notes 227-31 and accompanying text.

32. *See infra* note 227.

33. *See infra* note 228 and accompanying text.

34. *See infra* notes 232-42 and accompanying text.

35. *See* Hearing, *supra* note 5 (statement of Barry Scheck, Esq., Benjamin Cardozo Law School, New York). The DNA typing tests offered by private companies as well as the tests done by state crime laboratories are virtually unregulated. Several organizations, however, have adopted policy statements relating to use of DNA analysis in forensic laboratories. *See, e.g.*, AMERICAN ASSOCIATION OF BLOOD BANKS PARENTAGE COMMITTEE, PROPOSED STANDARDS FOR TESTS INVOLVING DNA POLYMORPHISMS (Nov. 1987); SOCIETY FOR FORENSIC HAEMOGENETICS, STATEMENT CONCERNING DNA POLYMORPHISMS (1987). These programs are completely voluntary and therefore provide relatively insignificant regulatory oversight. Further,

II. THE SCIENTIFIC TECHNOLOGY

Three DNA typing techniques are commercially available:[36] DNA Fingerprinting,[37] DNA-Print Identification test,[38] and Polymerase Chain Reaction (PCR).[39] The DNA Fingerprinting and DNA-Print techniques can be classified as restriction fragment length polymorphism (RFLP) comparison procedures, while the PCR technique can be classified as an allele-specific probe comparison procedure.[40] All the tests, with varying

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although there are state and some federal regulations governing DNA recombinant technology research, genetic screening, and parentage testing, the forensic application of DNA typing remains unregulated. The private firms offering the DNA typing test have established extensive and effective laboratory protocols and quality control guidelines and procedures. *See* Note, *DNA Identification Tests and the Courts*, 63 WASH. L. REV. 903, 927 n.26 (1988). In response to recent cases finding DNA typing evidence inadmissible due to inappropriate testing procedures, analysis, and interpretation of test results (see *infra* note 152 for a discussion of these cases), the New York State legislature formed the Forensic DNA Analysis Panel in August, 1988. The panel consists of prosecution and defense attorneys, scientists, legislators, legal scholars, and law enforcement experts. Pokemba, *DNA Evidence: Charting a Course for New York*, N.Y.L.J., June 12, 1989, at 2, col. 1. In September, 1989, the panel released a report and recommendations on guidelines and accreditation standards for DNA laboratories. "[T]he state recommended establishing a statewide DNA network, quality control and safety standards, equal access to testing, and an accreditation process to monitor public and private laboratories." Nance, *DNA Testing Legislation Weighed at Hearing*, N.Y.L.J., Nov. 9, 1989, at 1, col. 5, 25, col. 6. The panel also recommended creating an advisory committee, a scientific review board, and a DNA databank. *Id.* at 25, col. 6. The panel proposed the implementation of three regional DNA laboratories at a total cost of $1.4 million. In addition, Governor Cuomo announced he would earmark funding for an Albany laboratory with DNA typing capability. Spencer, *Panel Urges DNA Test Standards: Designated Labs, Legal Advisory Boards Suggested in Report*, N.Y.L.J., Sept. 7, 1989, at 2, col. 3.

36. Two other smaller biotechnology companies are also in the early stages of providing DNA typing commercially, Genetic Design Inc., located in Greensboro, North Carolina, Kolata, *supra* note 19, at A18, col. 5, and Genelex Corporation, located in Seattle, Washington, Watson, *supra* note 8, at 12, col. 1. Given the rapid development in this area, other techniques are sure to be developed in the near future. All three companies discussed in this Note — Cellmark, Lifecodes, and Cetus — currently use radioactive markers and electrophoresis to separate the different sized gene fragments. But a laser sequencing technique is being developed at E.I. Du Pont de Nemours & Co. and several other companies that would eliminate the need for radioactive materials and the intermediate step of electrically charging the sample. *See* Thompson, *supra* note 19, at 41. In addition, "Forensic scientists have recently been experimenting with a fourth approach to DNA typing, known as 'DNA sequencing.' . This procedure produces a direct read-out of the genetic code of DNA recovered from the scene of a crime and may become available for forensic use in a few years." Thompson & Ford, *supra* note 7, at 50-51 (footnote ommitted); *see id.* at 78-79. In addition to the commercially available techniques, the FBI uses 'DNA Profiling' in its own investigations, as well as offering the test to state and local police departments. *See supra* note 8.

37. *See supra* note 5.

38. *See supra* note 6.

39. *See supra* note 7.

40. *See* Thompson & Ford, *supra* note 4, at 57-59. Referring to the divergent

degrees of certainty, have one thing in common: they all investigate the characteristics of DNA as a method of identifying an individual.[41] The basis for DNA typing is grounded upon four interrelated suppositions: (1) that each individual, except identical twins, has a unique genetic configuration;[42] (2) that this unique genetic configuration is the same for all cells in which DNA is present;[43] (3) that the unique genetic configurations of each person are manifested through variable regions in the DNA;[44] and (4) that these variable regions can be measured as a point of comparison between samples for identity.[45] Some background knowledge of DNA is necessary to understand DNA typing.[46]

A. Background

The human body is composed of cells, and within the nucleus of each cell is the information needed to produce a complete individual.[47] This information is present in chromosomes, and the material of which they are made is DNA.[48]

> DNA in the cell is contained is packages called *chromosomes.* An individual inherits half of his or her chromosomes from each parent. The combined information encoded in the base sequences

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procedures, the authors explain:

> The approach to DNA typing used by Cellmark and Lifecodes breaks the DNA chain into fragments and examines the length of fragments that contain polymorphic segments . . . . The approach used by Cetus detects the presence of certain polymorphic DNA segments or "alleles" in the biological sample. Individuals differ in the alleles they possess . . . . If the length polymorphism approach is like using a magnet to find a needle in a haystack, allele specific probes are like using a metal detector to see if a particular type of needle is present or not.

Id. at 57-62. The FBI's "DNA Profiling" test is classified as an RFLP comparison procedure.

41. For a concise comparison of the three companies that offer the test and their procedures, see Thompson, *DNA Fingerprinting: Who Does It and How*, CAL. LAW., June 1988, at 41.

42. People v. Wesley, 140 Misc. 2d 306, 307, 533 N.Y.S.2d 643, 644 (County Ct. 1988).

43. *Id.* Over 99% of the cells of the human body contain DNA. The primary exceptions are red blood cells, which are non-nucleated. Id. at 307 n.4, 533 N.Y.S.2d at 644 n.4.

44. Certain areas of DNA are highly variable from one person to another. *Id.* at 314, 533 N.Y.S.2d at 649.

45. *Id.* at 314-315, 533 N.Y.S.2d at 649.

46. Judge Harris' opinion in *Wesley* is an excellent, understandable description of the process.

47. The human body contains approximately 10 trillion cells. DNA is present only in nucleated cells. *See infra* note 43.

48. *See* Kelly, Rankin & Wink, *Method and Applications of DNA Fingerprinting: A Guide for the Non-Scientist*, CRIM. L. REV. (London), Feb. 1987, at 105-06.

> of the inherited chromosomes is called the *genome*; this information determines the individual's physical chracteristics. Each body cell contains a completes set of chromosomes, a complete DNA "blueprint" for the entire person. No cell uses the entire "blueprint," however. Cells in different parts of the body read only the sections of DNA that they need to perform their functions.[49]

The structure of DNA was first described as a "double helix."[50] "This may be thought of as a sort of twisted ladder, with the rungs corresponding to [the bases]. Some have compared DNA structure to that of a zipper: two parallel strands, with teeth or bases pairing in the middle."[51] The sides of the DNA ladder are made up of alternating units of phosphate and sugar.[52] Each rung on the DNA ladder is known as a base pair. These bases are parallel chains known by their initial letters: A (adenine), G (guanine), C (cytosine), and T (thymine).[53] The specific sequence of these bases determines the particular instructions to the cells and provides the information required to assemble and regulate the construction of the body.[54] The combination of bases (base pairing) is very specific in DNA: "A will pair only with T, and C will pair only with G. A DNA strand can only be 'zipped

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49. *Id.* (emphasis added); *see also* People v. Castro, 545 N.Y.S.2d 985 (Sup. Ct. 1989):

> Each individual's DNA is apportioned into forty-six discrete sections within the nucleus of each cell. These sections are called chromosomes. Twenty-two of these chromosomes come from the mother and twenty-two come from the father. These are genetically arranged in pairs. Additionally, two sex-typing chromosomes, denominated "X" and "Y" are present.
>
> During reproduction the chromosome pairs of the mother and the father split apart and then recombine — one chromosome from the mother and one chromosome from the father — to create the "new" twenty-two chromosome pairs of their child. Females have two "X" chromosomes, and males have one "X" and one "Y" chromosome, thus giving each human a total of forty-six chromosomes.

Id. at 988-89.

50. *See Wesley*, 140 Misc. 2d at 310, 533 N.Y.S.2d at 645-46:

> In 1953, James Watson, an American scientist, and Francis Crick, a British scientist, working together at Cambridge University in England, discovered the chemical and spatial structure of the DNA molecule. It was a "double helix" in which two chains of nucleotides, running in opposite directions, are held together between pairs of bases reminiscent of the rungs of a ladder, and coiled like a spring. It looks like a twisted rope ladder or a spiral staircase. Wherever their derivation — human, animal, or vegetable — all DNA molecules have this shape.

Id.

51. Burk, *supra* note 5, at 457.

52. *See Wesley*, 140 Misc. 2d at 310, 533 N.Y.S.2d at 646.

53. *Id.* at 310-11, 533 N.Y.S.2d at 646.

54. *Id.* at 311, 533 N.Y.S.2d at 646.

up,' or *hybridized* with another strand that has a matching, complementary base sequence."[55] Each rung on the ladder consists of two bases, so the only possible combinations are A-T, T-A, C-G, or G-C. The order of the bases in one strand of the DNA ladder determines the order of the bases in the other strand; for example, if the bases in one strand of the ladder are ACTAGT, the bases in the opposite strand would be TGATCA.[56]

At intervals throughout the length of the DNA, bases randomly occur in certain combinations of three base pairs, known as codons.[57] Groups of codons form genes, which are units of inheritance composed of a segment of DNA that carries coded information associated with a certain trait.[58] Each gene is located at a specific site upon a specific chromosome, known as a locus.[59] Genes may be of varying lengths and follow one another along the DNA molecule.[60] Each gene differs from the next because the sequence or order of base pairs in one gene is different from the following one.[61] Alternate forms of genes are called alleles, for instance blond hair allele or brown hair allele.[62] The number of base pairs in a chromosome is extensive, and it has been estimated that only about forty-five percent of these are required for normal cell operation.[63] The purpose of the remaining fifty-five percent is not yet understood.[64] The "known" functional units are spread throughout the length of the DNA and are responsible for the formation of bodily components and traits, such as arms, legs, organs, and so forth.[65] Between these functional units lie what has been termed "anonymous sequences" or "junk DNA," which comprise the remaining fifty-five percent of "unknown" DNA.[66] In addition, the DNA ladder has

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55. Burk, *supra* note 5, at 457 (emphasis in original).

56. Kelly, Rankin & Wink, *supra* note 48, at 106.

57. *Wesley*, 140 Misc. 2d at 313, 533 N.Y.S.2d at 648.

58. *Id.*

59. *Id.*

60. *Id.*

61. *Id.* "About two-thirds of the genes are the same in almost all individuals but the rest vary from person to person. Since there are probably between ten thousand and one hundred thousand genes in humans and about one-third are variable, the number of possible combinations is inconceivably large." Greenwood & White, *supra* note 19, at 145.

62. "In chemical terms, the difference in alleles is explained by the difference in the ways the nucleotides, i.e., base pairs, arrange themselves along the DNA molecule." *Castro*, 545 N.Y.S.2d at 989. Each allele ranges from 1,000 to 10,000 base pairs. *Id.*

63. Kelly, Rankin & Wink, *supra* note 48, at 106.

64. *Id.*

65. *Id.*

66. *See Wesley*, 140 Misc. 2d at 314, 533 N.Y.S.2d at 649; *see also* Castro, 545 N.Y.S.2d

regions of repeated sequences throughout its length. These fragments, called "repetitive sequences" or "minisatellites," are also part of the DNA that seems to have no function.[67] The "unknown" regions of DNA vary enormously from person to person, and their length and number are different.[68] These areas are called polymorphisms, which means present in many forms, and provide the basis for DNA typing.[69] When these polymorphic regions are digested and spliced by the action of restriction enzymes, their varying lengths are capable of measurement.[70]

> Obviously if a DNA profile examined all three million sites of variation, each person's DNA could be individualized. Such an undertaking would be unduly burdensome in terms of time, labor, and cost. As an alternative to this approach, it is accepted that scientists can, in relative terms, discriminate between various people's DNA by examining several of these polymorphic sites. At a particular site or locus, a person may have a substantially unique pattern. For instance, a particular fragment size may occur in a small percentage of the population. By examining the sizes of a sufficient number of fragments at different sites on different chromosomes, statistical procedures permit enough discrimination to establish the unique configuration of any one person's DNA pattern.[71]

B. Methods

1. RFLP Comparison Procedure

The DNA typing process, both for Lifecodes and Cellmark, have six basic steps: (1) isolation, (2) digestion, (3) separation, (4) transfer, (5) hybridization, and (6) interpretation.[72] The first step entails extracting

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at 988 ("Of the three billion base pairs in a DNA molecule, approximately three million sites vary among individuals.").

67. *See* Kelly, Rankin & Wink, *supra* note 48, at 106; Burk, *supra* note 5, at 462.

68. *Wesley*, 140 Misc. 2d at 314, 533 N.Y.S.2d at 649.

69. CELLMARK DIAGNOSTICS LITERATURE, *supra* note 5, at 1. "The first polymorphisms were noted in the late 1970s and, since 1980, some 200 such polymorphisms have been defined." Sensabaugh, *supra* note 19, at 393.

70. *Castro*, 545 N.Y.S.2d at 990-91.

71. *Id.* at 989.

72. Hearing, *supra* note 5 (statement of Dr. Robert Shaler, Ph.D., Director Forensic Science, Lifecodes).

and purifying the DNA from collected biological samples.[73] The second step, sometimes referred to as digestion, is achieved through the use of restriction enzymes or restriction endonuclease.[74] This process is used to cut the long chromosomal chain into short pieces. The enzymes will cut the DNA only at very specific points; they act as "molecular scissors" because they recognize a specific base sequence in the DNA and cut the DNA only at that place.[75] Because the restriction enzymes cut only at their specific recognition sequences, digesting a person's DNA with a certain restriction enzyme will produce the same pieces every time.[76] The production of these specific fragments is a recognizable characteristic and is inheritable. Because every nucleated body cell contains a complete copy of a person's DNA, the same fragments should be produced by cutting DNA from any body cell.[77]

Thus, a person's blood can be compared to his own hair root, and the DNA would be cut up in the exact places in each sample when using the same restriction enzyme.[78] The number and length of DNA fragments generated by a particular restriction enzyme depend on where and how often the enzyme's base sequence occurs in the DNA specimen. Theoretical-

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73. For example, if the laboratory received a swatch of fabric containing dried semen, the fabric would be cut up into small pieces, scrubbed in a buffered saline solution, and then soaked and mildly agitated for 24 hours. The solution would then be compressed through nylon mesh to extract the fabric and then centrifuged to isolate the spermatozoa. Baird, Balais, Giusti, Glassberg & Pasquale, *Application of Deoxyribonucleic Acid (DNA) Polymorphisms to the Analysis of DNA Recovered from Sperm*, 31 J. FORENSIC SCI. 409, 410 (1986).

74. *Wesley*, 140 Misc. 2d at 315, 533 N.Y.S.2d at 649.

75. *Id.* at 315-16, 533 N.Y.S.2d at 649; *see also Castro*, 545 N.Y.S.2d at 991:

> For example, the restriction enzyme known as PST-1 (Providentia Stuarti #1) recognizes the base pair sequence CTGCAG and cuts the DNA between the A and G nucleotide. Thus, the enzyme will cut the DNA molecule at this specific "A-G" point at all places throughout the entire three billion base pairs in which the six base pair sequence occurs.

Id.

76. Burk, *supra* note 5, at 457-58.

77. Id. at 458.

78. Because enzymes recognize different sequential patterns in the DNA, it is unfeasible at this point to compare test results on two or more samples if different restriction enzymes were used on the samples. A similar problem arises when different probes are used. Thus, to establish identity by matching two biological samples, the same enzyme/probe combination must be used on each sample. Each combination has a distinct power of identity. This also becomes an important practical problem with the implementation of a DNA database; where different testing companies are used for different samples, there is no way to compare those results. Thus, DNA database is useful only if the databank results were done with the same enzyme/probe combination as the sample to which it would be compared.

ly, a restriction enzyme would cut everyone's DNA in the same places, resulting in same-size fragment lengths.[79] However, since every person's DNA contains polymorphic regions scattered throughout their DNA, the cut points in those areas are shifted, resulting in fragments of varying length.[80] These fragments are called restriction fragment length polymorphisms (RFLPs).[81] Different restriction enzymes recognize different sequences.[82]

The third step in the process involves the separation of the cut-up pieces of DNA and is called gel electrophoresis.[83] This process separates the DNA fragments on the basis of their length.[84] The fragments are placed in a slot cut into a flat plate of gelatinous material (like Jell-O). The gel is placed in a tray of electrolyte solution and an electric current is applied through the solution.[85] Because DNA fragments have a negative electrical charge, they will migrate toward the positive electrode at the other end of the gel. The smaller pieces move faster, the larger ones more slowly, so that eventually the DNA is spread out in a strip extending from the slot to the other end of the gel.[86] Unfortunately, the DNA is invisible, so one cannot see directly how far the various fragments have travelled.[87] "To mark

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79. *Wesley*, 140 Misc. 2d at 315, 533 N.Y.S.2d at 649.

80. *Id.*; *see also Castro*, 545 N.Y.S.2d at 991:

> In the anonymous or polymorphic sequence, where there are vast differences in the way the base pairs are arranged, there will be great differences in the length of the fragment because of the varying number of base pairs that lie between the cutting points that the restriction enzyme selects. These varying number of base pairs are known as "Variable Number of Tandem Repeats" or repeat sequences of DNA base pairs which vary in length. They are called "VNTRs" for short. The varying lengths of fragments, produced by VNTRs, after the DNA is cut by the restriction enzyme, are known as "Restriction Fragment Length Polymorphisms" or "RFLPs."

Id.

81. Burk, *supra* note 5, at 461. These enzymes occur naturally as a defense mechanism in certain bacteria. Scientists have been able to isolate these enzymes and study their effects on DNA. Certain enzymes recognize specific sequences in the DNA. For instance, if a sequence were AGTC paired with TCAG (remember A pairs only with T and C only with G, *see supra* text accompanying notes 53-56), and the enzyme were known to recognize and cleave that sequence, the long strand of DNA would be cut into pieces at those points. The number of cleaves depends upon the frequency of that sequence in the DNA. *See* Kelly, Rankin & Wink, *supra* note 48, at 107.

82. Burk, *supra* note 5, at 457.

83. *Wesley*, 140 Misc. 2d at 315, 533 N.Y.S.2d at 649.

84. Burk, *supra* note 5, at 459. The gel is usually agarose. *Id.*

85. *Id.*

86. *Wesley*, 140 Misc. 2d at 315-16, 533 N.Y.S.2d at 649.

87. Burk, *supra* note 5, at 459.

the RFLPs for further measurement, the entire gel is treated with ethidium bromide. All of the DNA absorbs the stain and glows when placed in the ultraviolet light. Thus, it is possible to determine where the DNA is located on the gel and to photograph its position."[88]

Step four involves the process by which these fragments are "fixed."[89] This step involves chemically splitting apart the two strands (sides of the ladder) of the DNA, transferring and permanently fixing the fragments in exactly the same positions they occupied in the gel onto a sheet of nitrocellulose filter (or nylon membrane).[90] This process is called Southern blotting, named for its inventor.[91]

The fifth step is called hybridization.[92]

> To identify the aspects of the DNA pattern unique to each individual, "probes," developed in the laboratory by the use of recombinant DNA technology, are applied to the nitrocellulose membrane. These probes are tagged with a radioactive marker substance and are designed to seek out a pre-determined locus in a polymorphic (highly variable) region of the DNA. Upon finding a DNA fragment that carries all or part of its complementary base sequence, the probe will bind to the fragment. The marker component of the probe will cause the probe-bound fragment to "light-up," allowing easy identification of their positions in the fragment pattern.[93]

The final step is the interpretation of the results. The excess probe is washed away and the nitrocellulose sheet is placed against a piece of x-ray film and exposed for several days.[94] When the film is processed, black bands appear where the radioactive probes adhered to the fragments. The appearance of the bands on the x-ray is called an autoradiograph (autorad).[95] The pattern of the bands on the film is a DNA print.

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88. *Castro*, 545 N.Y.S.2d 985, 991 (Sup. Ct. 1989).

89. Burk, *supra* note 5, at 460.

90. *See Wesley*, 140 Misc. 2d at 316, 533 N.Y.S.2d at 649-50.

91. Southern blotting is named after its inventor, Dr. E.H. Southern, who reported the process in 1975. *Id.* at 316, 533 N.Y.S.2d at 650.

92. *Id.*

93. *Id.* (footnotes omitted).

94. *Id.*

95. Burk, *supra* note 5, at 460.

> Each band on the print thus indicates the location . . . of a polymorphic DNA segment. The location of each segment . . . is, in turn, an indication of the length of the DNA fragment that contains that segment. Because there is variation among individuals in the length of DNA fragments that happen to contain polymorphic DNA segments, people may differ in the position of their bands on a DNA print.[96]

The basic difference between the technique used by Lifecodes and that used by Cellmark lies in the type of probes used to make the DNA print. Lifecodes uses single-locus probes, which attach to a polymorphic DNA segment that occurs only once on the human DNA chain.[97] Since "all chromosomes are present in duplicate, the resulting DNA print generally has two bands—one inherited from the mother and one from the father (although only a single band will appear where the maternal and paternal genes are identical)."[98] Because more than one individual may have that same polymorphic region, Lifecodes uses four different single-locus probes to produce a sufficiently high probability that few people have those exact combinations.[99] "The Cellmark test uses multi-locus probes [for paternity testing], which seek and find polymorphic DNA segments that occur at many locations in human DNA. These probes produce about [fifteen] interpretable bands."[100] For criminal DNA typing, Cellmark recently has switched to a single locus probe, much like that used by Lifecodes.[101]

Once the autorad is produced, the bands appearing in the several lanes of the autorad are examined to determine if a match is present:[102] a match occurs when the bands on the vertical lanes line up in the same space when reading across the lanes horizontally.[103] The normal procedure

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96. Thompson & Ford, *supra* note 4, at 59.

97. *See* Burk, *supra* note 5, at 460.

98. Thompson & Ford, *supra* note 4, at 62.

99. *Wesley*, 140 Misc. 2d at 316, 533 N.Y.S.2d at 650.

100. Thompson & Ford, *supra* note 4, at 62.

101. Thompson & Ford, *supra* note 7, at 49.

102. *See Castro*, 545 N.Y.S.2d 985, 992 (Sup. Ct. 1989) ("A match is said to occur if the sizes and number of the detected RFLPs in the various lanes are indistinguishable within a permissible degree of error.").

103. Each sample upon which a DNA typing test is performed is assigned a "lane." For instance, if a biological sample was found on the victim's clothes, a DNA typing test would be done on that sample and, to determine its origin, it would be compared to a biological sample taken from the victim and a biological sample taken from the suspect. The crime scene sample is assigned lane A, the victim's sample is assigned lane B, and the

for evaluating the autorad is by visual examination by a trained scientist, but machines are also available to analyze the DNA prints and to assign each one a numerical code.[104] If a match is found, the inquiry then focuses on the matching DNA prints' frequency in the population at large, using statistical data derived from population testing and studies.

The frequency of a given band and the DNA print as a whole is based on population genetics.[105] "Population genetics derives its force for

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suspect's sample assigned lane C. Lane A would be compared to lane B to determine if the crime scene sample originated from the victim. If they were found to match, that evidence would have little probative value for criminal investigatory purposes. If no match was found, lane A would be compared to lane C to determine if the crime scene sample originated from the suspect. If they were found to match, that evidence has substantial evidentiary value in associating the suspect to the crime scene and the victim. If those lanes were found not to match, that result would either signify to investigators that the suspect was not involved in the crime at all or, if other strong evidence existed connecting the suspect with the crime, that another individual was involved.

104. Thompson & Ford, *supra* note 7, at 74:

> There are two different kinds of machines. Standard densitometry uses lasers or video cameras to "count" the grains in the photographic emulsion of the autoradiograph. A more direct approach is used by [Automated Microbiology Systems, Inc.] which has been successfully marketing a machine designed to read radioactive blots to research laboratories. This machine detects the radioactivity on the membrane after hybridization, thereby avoiding autoradiography.

Id. at 75 n.140; *see also Castro*, 545 N.Y.S.2d at 998:

> Lifecodes declares a match by visual observation in a blind reading of the audoradiograph. This appears to be accepted by the scientific community. The Court accepts that scientists can properly declare a match visually on an audioradiograph, quantify that match by computerized measurement, and then compare those measurements to the data pool. The quantitative measurements should confirm the visual match. If they do not, and it is unexplained, an exclusion should be announced. If the measurements confirm the visual match, the evaluation of the frequency of the allele in the population will be conducted, using an acceptible data pool.

Id. (footnote omitted); *see also* State v. Pennell, No. IN-88-12-0051 (Del. Super. Ct. Sept. 25, 1989):

> Cellmark is using bioimaging technology that uses computer scanning to measure the autorad bands for purposes of inputing the allele length into a population data base. This eliminates to a greater degree the possibility of human difference in the data entry. It does not remove that problem, however, as it is conceded by Cellmark that the bioimager cannot read all autorads, and it is incapable of discerning an imperfection on the autorad from a band. When this occurs the placement of the location of the band and, hence, the estimate of allele lengths is accomplished by concensus of three scientists, who together read the autorad and agree upon an estimated length.

Id.

105. *See Castro*, 545 N.Y.S.2d at 992:

> The population geneticist determines the frequency with which a specific allele occurs within a given human racial group. In the case of a common allele, for

identification purposes from the small likelihood that a given polymorphic or anonymous allele will occur randomly in the relevant racial population."[106] Randomness in a population's development of alleles is a crucial factor in the calculations that derive the astronomical probabilities associated with DNA typing evidence.[107] In turn, the randomness of the alleles depends upon their independence from one another.

Obtaining an accurate statistical probability of a coincidental match between unrelated individual samples depends on the independence of bands produced by the probes used in the DNA typing test. "The bands are said to be independent if the probability of a match on each band is unaffected by the occurrence of a match on any other band. If they are independent, the probability of a match on multiple bands can be computed [by] appyling the product rule."[108] The following criteria define a band's independence: (1) the alleles identified by each of the probes must be in what is called "Hardy-Weinberg equilibrium"; (2) the alleles identified by each of the probes must not be affected by "linkage disequilibrium"; and (3) the occurrences of alleles identified by each of the probes must not be more frequent than usual among ethnic subpopulations or geographical areas.[109]

The first criteria for discerning the independence of alleles produced

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example the Rh positive blood types, the frequency of occurrences in the human population is quite large. Thus, if both DNA samples show the Rh positive allele, the population geneticist can say only that both samples could have come from any person, male or female, who is part of the majority of the human population. In the case of the Rh negative allele, the population geneticist can say that the allele is somewhat rarer and that the samples come from a minority of the human population. In the case of alleles that occur in the anonymous or polymorphic section of the genome the likelihood that the samples will match is much smaller. This reduced likelihood of matches is what gives DNA identification technology its value for forensic purposes.

Id.; *see also* Thompson & Ford, *supra* note 7, at 81:

> The probability that two unrelated individuals will have identical DNA prints on the Cellmark or Lifecodes tests depends most obviously on the number of bands the two DNA prints have in common and the rarity of the matching bands. Other things being equal, the likelihood of a coincidental match decreases as the number of matching bands and the rarity of those bands increases.

Id.

106. *Castro*, 545 N.Y.S.2d at 992.

107. See *supra* notes 12-15 for examples of the probabilities associated with DNA typing tests that have been submitted in criminal trials. The method by which those probabilities are derived is discussed *infra* notes 121-26 and accompanying text.

108. Thompson & Ford, *supra* note 7, at 81 (footnote omitted). See *infra* text accompanying notes 121-22 for a discussion of the product rule.

109. Thompson & Ford, *supra* note 7, at 85-86.

by a set of probes is the existence of Hardy-Weinberg equilibrium.

> There is evidence . . . that the inheritance of the bands produced by the Lifecodes and Cellmark probes is Mendelian—one band comes from each of the individual's parents. As a general rule, where there is Mendelian inheritance the likelihood of receiving a particular band from one parent is not influenced by (or related to) the band received from the other parent, and hence the bands are independent. Where this occurs there is said to be Hardy-Weinberg equilibrium.[110]

As long as mating remains constant and follows Mendelian inheritance, allele frequencies are assumed to remain constant through generations.[111]

The second criteria determines whether alleles found by different probes occur more frequently together because of close proximity on a chromosome. For instance, two alleles occuring on the same chromosome are more likely to be passed on together from parent to child. When this happens, the chance that those alleles were randomnly passed on is diminished. When the occurrence of alleles is not random because of this phenomenon, linkage disequilibrium ensues and the alleles are not independent.[112] "Where the alleles occur on different chromosomes, linkage is not expected to occur except due to external forces of nature. Where there is no linkage, the appearance of the allele may be said to have occurred randomly."[113] Thus, linkage disequilibrium may be minimized by the use of probes which search for alleles that are on different chromosomes.[114]

The third criteria concerns whether certain ethnic subgroups or individuals within specific geographical areas may exhibit a different frequency of alleles than the general population or larger geographical

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110. *Id.* at 85; *see also Castro*, 545 N.Y.S.2d at 992:

> The Hardy-Weinberg principle is expressed algebraically as P2 + 2PQ + Q2, where P and Q are the percentage of the population having two different alleles. Where, for example, P and Q are Rh positive and Rh negative respectively and where Rh positive blood is seen in 60% of the population and Rh negative blood is seen in 40% of the population, the equation tells us that P2 = .36, 2PQ = .48 and Q2 = .16. Since these numbers total 1, the population is in Hardy-Weinberg equilibrium for these alleles.

Id.

111. *Castro*, 545 N.Y.S.2d at 992.

112. *Id.* at 992-93.

113. *Id.* at 992.

114. Thompson & Ford, *supra* note 7, at 85.

regions. "It is possible . . . that certain population subgroups have fewer alleles than found in the population at large. Within a given subpopulation certain bands might simply not occur while others occur with far greater frequency than in other subgroups."[115]

The investigation into alleles' independence requires extensive population studies empirically evaluating the frequency of a given allele or groups of alleles in the population.[116] "To simply assume, without empirical verification, that distinct alleles are independent could allow misleading statistical testimony which greatly underestimates the probability of a coincidental match."[117] In the case of the third criteria, extensive population studies into specific and separate ethnic subpopulations and specific geographical areas is necessary.[118]

Aside from the independence issue, an allele frequency study is usually necessary to calculate the frequency of bands appearing in the single-locus probe DNA typing tests.[119]

> Each single-locus probe produces one or two bands. The position of these bands indicates the length of the restriction fragments located by the probe. A fragment of given length is known as an allele. The fragments located by the single-locus probes used in DNA typing typically have thirty to eighty different alleles and therefore may produce bands in thirty to eighty different positions. The goal of an allele frequency study is to determine the frequency in the population of each of the alleles identified by the probe
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> . . . .
>
> For criminal identification, Lifecodes and Cellmark typically

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115. *Id.* at 86; *see also DNA Evidence Can Be Flawed, Researcher Says*, *supra* note 19, at 14 col. 3. Eric Lauder, of the Whitehead Institute for Biochemical Research in Cambridge, Massachusetts, said that in a rape and murder case:

> a laboratory estimated there was only a one-in-96 million chance that samples it matched came from different people. But the calculations did not take into account that the crime occurred "in a small, inbred, Texas town founded by a handful of families," where the restricted genetic variation would make it more likely that matching samples could come from separate residents.

Id.

116. Thompson & Ford, *supra* note 7, at 82 n.172.

117. *Id.* at 82.

118. *Id.* at 86.

119. *Id.* at 83.

> use three or four probes and hence have six to eight bands to work with when comparing samples. If two samples match, the companies report the match and the frequency in the population of the set of alleles which the samples share.[120]

If the independence of alleles is established, the rarity of the bands produced by the DNA typing test occuring in the general population is determined by the probability of a coincidental match between unrelated individuals. This type of statistic is required because absolute figures cannot be generated by sampling less than the total population. To derive the frequency of a specific DNA print, the alleles produced by the DNA print are compared to the frequency of those same alleles in the population database. Based on the population data, the alleles are assigned a certain frequency, i.e., if one allele occurs in one out of one hundred people, its frequency would be .01. Assuming independence of alleles, the product rule is used to calculate the probabilities of a coincidental match.[121] This rule states that the probability of independent events occuring simultaneously is calculated by multiplying the probabilities of each event. For example, if three probes are used, producing alleles A, B, and C and if each allele was assigned a frequency of .01 based on population data, then the probability of all events occuring simultaneously would be .01 X .01 X .01 = .000001 or one in a million.[122]

If the alleles fail to meet any of the three criteria mentioned above, they are not independent, and therefore, the product rule is an inappropriate measure of probability. "[T]he degree of dependency between the alleles must be calculated. Calculations may also be obtained by finding the actual, not projected, frequency in the population. This may be accomplished using larger populations, reference populations to determine genotype frequencies, or by considering only one allele."[123] In a frequent but questionable practice, courts have corrected nonindependence by reducing the probability by a certain factor,[124] or even accepting the lowest probability offered by the testing laboratory.[125] "The issue of independence, and the appropriateness

120. *Id.* at 84 (footnotes omitted).

121. *Id.* at 81.

122. *See id.* at 81-82.

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

124. *See supra* notes 12-13.

125. *See* People v. Huang, 546 N.Y.S.2d 920 (County Ct. 1989) (use of DNA Fingerprinting allowed subject to limitation of expert's testimony to lowest proposed figured

of the ad hoc adjustment of the numbers . . . are likely to be important issues in future cases."[126]

2. Allele-Specific Probes

The second approach to identifying DNA polymorphisms is used by Cetus Corporation in its PCR test.[127] The PCR test uses allele-specific probes to determine whether a specific allele is present in a biological sample.[128] First, the DNA is purified.[129] Second, the DNA is heated or "denatured," a process that separates the double-stranded DNA into single strands.[130] The strands (sides of the ladder) are then lined up one in front of another. In the third step, the DNA is "amplified" by a process called polymerase chain reaction, which increases the number of copies of a polymorphic allele present in the biological sample by heating and cooling the DNA with an enzyme called DNA polymerase.[131]

Short pieces of DNA called primers—synthetic bits of DNA that search out and chemically bond to a particular pattern of base sequences along each strand of DNA—are added.[132] The primers attach to one end of each strand of the sample so that the two flank the segment that is to be copied. These primer pieces define the portion of DNA to be copied and provide chemical instructions.[133] Each primer carries a "copy" instruction that instructs the DNA to begin copying itself.[134] This copying is enhanced by the DNA polymerase enzyme, which attaches to the end of the primer.[135] DNA polymerase enzyme is a natural substance that copies a piece of DNA

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probability).

126. Thompson & Ford, *supra* note 7, at 105.

127. Since PCR technology has not been widely used, it will not be discussed in detail in this Note. For a discussion of this technology, see Thompson & Ford, *supra* note 4, at 62.

128. *Id.* For a definition of allele, see *supra* note 62 and accompanying text.

129. Thompson & Ford, *supra* note 4, at 62.

130. Foreman, *DNA Test Exceeding Hopes—In Many Fields*, Boston Globe, Sept. 5, 1988, at 29, col. 2.

131. Schmeck, *New Test That Finds Hidden AIDS Virus Is a Sleuth with Value in Many Fields*, N.Y. Times, June 21, 1988, at C11, col. 3.

132. Foreman, *supra* note 130.

133. *Id.*

134. *Id.*

135. *Id.*

when it finds the proper instruction signals on the strand it encounters.[136] It assembles a second matching strand of DNA along each original so that a new double helix of DNA is produced.[137] The first PCR reaction yields two identical double-stranded chains of DNA, the second yields four, the third, eight, and so on. As long as the initial quantities of primer and polymerase are sufficient, the process is self-replicating, each cycle yielding twice as much DNA as the cycle before.[138] Even if the sample has only one or two alleles, PCR will increase the number to about ten million.[139]

> The amplified DNA sample is "spotted" onto a membrane, and a probe is added. If the allele being sought by the probe is present, the probe will lock onto it, making the spot radioactive. When the membrane is placed on X-ray film, a dark dot will appear on the film if the allele being sought is present. . . . The test gives a simple yes or no answer. A single yes-no probe may not be useful for distinguishing individuals because a significant percentage of the population may have a given allele. By using a series of these probes, however, the analyst can narrow the percentage of the population that could have been the source of a sample.[140]

C. Application and Advantages

DNA typing is most useful in murder and rape cases. In these instances, biological samples left by the perpetrator are most likely to be found. DNA typing also has particular application in paternity suits. However, it has been claimed to be applicable in any crime in which biological evidence from the assailant can be retrieved for laboratory evaluation.[141] These cases would include assault, robbery, serial crimes, missing persons, victim identification, immigration cases,[142] and hit-and-run cases.[143]

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136. *Id.*
137. Schmeck, *supra* note 131.
138. *Id.*
139. Thompson & Ford, *supra* note 4, at 62.
140. *Id.*
141. LIFECODES BACKGROUND INFORMATION, *supra* note 6, at 8.
142. *Id.* at 13.
143. *Id.* at 9.

The exact number of cases that have admitted DNA evidence is difficult to ascertain because only one state supreme court ruling,[144] a few appellate decisions,[145] and unreported trial court decisions exist. In addition, a defendant—whether in a criminal suit or in a paternity suit—confronted with DNA evidence frequently will plead guilty or agree to a plea bargain.[146] The circumstances of those pleas with respect to whether the DNA evidence was a decisive element has not been the subject of study. As of May, 1988, Lifecodes stated that it had done DNA-Print tests in about two thousand paternity cases and four hundred criminal cases.[147] About seventy-five percent of the criminal cases were rape cases, in which most defendants pleaded guilty after the results of the DNA typing were determined.[148] It was reported in January, 1988 that most of the 150 defendants tested by Lifecodes since January, 1987 pleaded guilty.[149] Cellmark stated that it has done DNA Fingerprinting in about fifty criminal cases and about fifty paternity cases.[150]

The first criminal cases using DNA typing were in England, and, as of September, 1988, it has been used there in more than twenty criminal cases.[151] Until August 14, 1989, the DNA Fingerprinting test and

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144. Spencer v. Commonwealth, 238 Va. 563, 385 S.E.2d 850 (1989), *cert. denied*, 110 S. Ct. 759 (1990).

145. *See* State v. Martinez, 549 So. 2d 694 (Fla. Dist. Ct. App. 1989); Hill v. State, 535 So. 2d 354 (Fla. Dist. Ct. App. 1988); Andrews v. State, 533 So. 2d 841 (Fla. Dist. Ct. App. 1988), *review denied*, 542 So. 2d 1332 (Fla. 1989); Yorke v. State, 311 Md. 386, 535 A.2d 465 (1988), *retrial denied*, 315 Md. 578, 556 A.2d 230 (1989); State v. Schwartz, 447 N.W.2d 422 (Minn. 1989); Commonwealth v. Spencer, 238 Va. 275, 384 S.E.2d 775, *aff'd*, 238 Va. 563, 385 S.E.2d 850 (1989), *cert. denied*, 110 S. Ct. 759 (1990).

146. *See, e.g.*, Moss, *supra* note 19, at 67, 70. One law enforcement official has stated that DNA typing evidence "not only helps us at trial, it helps the defendant see the writing on the wall when it comes to a decision between going to trial and pleading on the charges." *Id.* at 70 (quoting Doug Beam, prosecutor in Hill v. State, 535 So. 2d 354 (Fla. Dist. App. Ct. 1988)).

147. Thompson & Ford, *supra* note 4, at 57.

148. Moss, *supra* note 19, at 67. The number of tests performed increases by a few hundred every week. Note, *supra* note 35, at 917 n.64.

149. *Admission of DNA Fingerprints Prompts Queries*, Nat'l L.J., Jan. 18, 1988, at 42, col. 4.

150. Moss, *supra* note 19, at 68.

151. Thompson & Ford, *supra* note 4, at 56; *see also* CELLMARK DIAGNOSTICS LITERATURE, *supra* note 5 (citing cases in which DNA Fingerprinting was admitted as evidence and led to identifications and convictions).

DNA-Print test had never failed to meet the evidentiary standards in any court in which they had been offered.[152] In the first decision of its kind,

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152. "Although defense lawyers... are challenging [DNA typing] and the interpretation of [test results]..., the basic science has gone virtually unquestioned in more than 80 court cases in the last two years as prosecutors seek to construct a frame-work of legal precedents." Malcolm, *supra* note 8, at 1, col. 7. "In the first two dozen cases where DNA evidence was introduced, the opposing attorney did not even challenge the evidence,... they felt scientifically illiterate and unable to even perceive of question. No adverse experts were even retained by the counsel. Everyone just sort of [laid] down and died." Kolata, *supra* note 19, at A18, col. 6; *see also* Olivas, *supra* note 18.

August 14, 1989 is the date the New York case of People v. Castro, 545 N.Y.S.2d 985 (Sup. Ct. 1989), was handed down. It was the first case to substantively limit the admission of DNA typing evidence. Although the Court held that the underlying theories of DNA typing passed muster under the *Frye* test, it held that the evidence purporting to match a bloodstain from the defendant's watch to the victim was inadmissable because the laboratory (Lifecodes) failed in major respects to use generally accepted techniques and experiments for obtaining reliable results. This decision was reached after a pre-trial hearing "that some have referred to as the most comprehensive and extensive legal examination of DNA forensic identificaiton tests held to date in the United States .... [It] took place over a twelve week period producing a transcript of appproximately five thousand pages." *Castro*, 545 N.Y.S.2d at 986. The decision was made in part because, in a pre-trial move, both defense and prosecution experts agreed that the samples were so "flawed that it rendered them unreliable." Anderson, *supra* note 19, at 18. Lifecodes, nevertheless, stood by its original assumption that the samples matched. *Id.*

Other cases finding DNA typing inadmissible are State v. Schwartz, 447 N.W.2d 422 (Minn. 1989) (DNA evidence submitted by Cellmark failed to comport with quality control guidelines for DNA developed by the FBI, the technical working group in DNA analysis methods, and the California Association of Crime Laboratory Directors, and defendant did not have access to testing data and results because they were not made available); State v. Pennell, No. IN-88-12-0051 (Del. Super. Ct. Sept. 25, 1989) (court found DNA typing procedures to be based upon generally accepted scientific principles, but found serious fault in Cellmark's database of statistical frequencies of DNA found in the popluation and found them not reliable; Cellmark did not sufficiently provide the defendant with its statistical calculations of both its probes and its database); State v. Woodall, 385 S.E.2d 253 (W. Va. 1989) (court denied the defendant's request to submit DNA typing test because it failed to meet the relevancy standard; test proved inconclusive, which meant it neither included nor excluded the defendant, and thus the court ruled it had no probative value). It is interesting to note that by legislative enactment, Minnesota now allows the admissibility of DNA typing evidence under the relevancy approach. State v. Schwartz, 447 N.W.2d at 425 n.2.

Prior to the *Castro* decision, defense lawyers were tremendously limited in their ability to effectively challenge DNA typing: (1) DNA typing was so new in its application to forensic science that there was little published data on the variance in its reliability from pristine laboratory conditions evident in prior DNA typing applicaitons to the very unstable environmental conditions of samples taken from crime scenes in addition to the controls necessary to compensate for these adverse conditions; (2) there existed a conspicuous lack of "disinterested" scientific experts able to refute or at least challenge the procedures, analysis of results, and the accuracy of the population databases of the commercial companies; and (3) a significant portion of the company's test substances and protocol measures were

Justice Sheindlin, in *People v. Castro*,[153] found DNA typing evidence inadmissible in a pre-trial hearing. The defendant was charged with two counts of second degree murder. The prosecution sought to introduce evidence that a blood stain found on the defendant's watch at the time of his arrest matched the victim's blood.[154] While the court acknowledged that DNA typing is generally accepted in the scientific community under the *Frye* test and allowed the admission of the DNA type result excluding the blood on the watch as that of the defendant, it held the DNA type result including the blood on the watch as that of the victim's inadmissible because the testing laboratory failed to use generally accepted scientific techniques and experiments for obtaining reliable

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"trade secrets," which allowed only limited discovery among a limited number of scientists. Most of these problems continue to exist for defense lawyers, but the decision in *Castro* at least bolsters increasing assertions that DNA typing is not infallible.

> Barry C. Scheck and Peter Neufeld, the New York-based defense team in [*Castro*] who also head the National Association of Criminal Defence Lawyers' DNA Task Force, say they will actively campaign for retrials of all cases in which Lifecodes conducted the DNA analyses.
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> "It is our view that DNA-based evidence should not be used in court proceedings at all," Scheck said. "If if is ever used, the laboratories processing it should be held to the strictest standards that would meet all previously recognized tests for the admission of scientific evidence."

Anderson, *supra* note 19, at 18. "The experts' conclusions [in *Castro*] forced prosecutors to drop their contention that the blood came from the victim and set the stage for the reopening of some 60 convictions in 27 states that have hinged on similar DNA-related analyses." *Id.* State Supreme Court Justice Gerald Sheindlin, who presided over *Castro*, also "urged lawyers in previous DNA cases to re-examine their trial records to see if appeals were warranted on the basis of his opinion." *DNA Test Inadmissible*, *supra* note 19, at 1, col. 2. Dr. Thomas G. Marr, a molecular biologist at Cold Spring Harbor laboratory, was recently quoted in an article saying that DNA Typing "is being sold as absolute and without error, and that's wrong. Before I'd start convicting people based on this technology, I'd want to study it in much greater detail. There are several reasons, both theoretical and practical, that justify that careful attention be paid to this." Kolata, *supra* note 19, at A18, col. 4-5; *see also* Olivas, *supra* note 18. In the same article, three of the scientific experts interviewed expressed some reservations about the accuracy of DNA typing when asked if they would rely on DNA typing to vindicate them if they were accused of committing a crime but were innocent. Kolata, *supra* note 19, at A18, col. 6. FBI officials stated in regard to the *Castro* case that the technology was not questioned, but only the technique used prior to and in that case. That technique is no longer used. Malcolm, *supra* note 8, at 14, col 4. See *supra* notes 162-78 for a discussion of the limitaions of DNA typing.

153. 545 N.Y.S.2d 985 (Sup. Ct. 1989).

154. *Id.* at 985.

results.[155] Thus far twenty-seven states have admitted DNA typing evidence in criminal trials.[156]

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155. *Id.* at 999.

156. The states are Alabama, California, Colorado, Delaware, Florida, Georgia, Hawaii, Idaho, Illinois, Indiana, Kansas, Kentucky, Louisiana, Maine, Maryland, Michigan, Minnesota, New York, North Carolina, Ohio, Oklahoma, Oregon, South Carolina, Texas, Washington, West Virginia, and Virginia.

Apparently, the first criminal case in the United States in which DNA typing evidence was used was State v. Hunt, No. CRF861541 (Norman, Okla., Sept. 15, 1987), discussed in Moss, *DNA-The New Fingerprints*, A.B.A. J., May 1, 1988, at 66, 68. In *Hunt*, the defendant was suspected of murder and DNA typing evidence was introduced after an evidentiary hearing. The evidence connected blood from the hose of the defendant's vacuum cleaner to that of a missing person suspected to be dead. Lifecodes tested the victim's parents to determine the missing person's DNA type. *Id.* The defendant was acquitted, but the prosecutor believes the acquittal was based not on the jury's disbelief of the DNA evidence, but rather on the fact that the victim's body was not found. Telephone interview with Michael Keene, of Breed, Abbott & Morgan, Counsel for Lifecodes (Nov. 11, 1988).

The first DNA typing case to reach an appellate court was Andrews v. State, 533 So. 2d 841 (Fla. Dist. Ct. App. 1988), *review denied*, 542 So. 2d 1332 (Fla. 1989). In that rape case, there were no witnesses, the victim could not identify the defendant, and the defendant had an alibi. The defendant was convicted and received a 22-year prison sentence. The conviction hinged almost exclusively on results of the DNA typing test done by Lifecodes which was admitted after an evidentiary hearing. The Fifth District Court of Appeals affirmed the conviction and the admissibility of the DNA typing. Subsequent appellate decisions include State v. Martinez, 549 So. 2d 694 (Fla. Dist. Ct. App. 1989) (statistical evidence concerning likelihood that DNA from crime scene semen sample and DNA from defendant's blood sample were taken from same person was admissible); Hill v. State, 535 So. 2d 354 (Fla. Dist. Ct. App. 1988) (defendant's conviction for, *inter alia*, sexual battery reversed on appeal and a new trial ordered; court ruled that defendant's due process rights were violated because he was not given sufficient time to permit reasonable investigation regarding the prosecution's scientific expert on DNA typing); Yorke v. State, 311 Md. 386, 535 A.2d 465 (1988) (DNA Fingerprinting held admissible in an evidentiary hearing in a rape case), *retrial denied*, 315 Md. 578, 556 A.2d 230 (1989) (convicted defendant not entitled to new trial on basis of newly discovered evidence showing that DNA pattern in victim's vaginal washings did not match pattern of defendant's DNA); State v. Schwartz, 447 N.W.2d 422 (Minn. 1989) (admissibility of DNA testing is governed by *Frye* standard; evidence is admissible if tests are performed in accordance with appropriate laboratory standards and control); Commonwealth v. Spencer, 238 Va. 275, 384 S.E.2d 775, *aff'd*, 238 Va. 563, 385 S.E.2d 850 (1989) (two trials, both admitting DNA Fingerprinting after *Frye* hearing; defendant convicted of multiple rape/murders and sentenced to death), *cert. denied*, 110 S. Ct. 759 (1990).

Among the other criminal cases in which DNA typing evidence was admitted are Kennedy v. State, 545 So. 2d 214 (Ala. Ct. App. 1989); People v. Axell, No. CR-23911 (Ventura Super. Ct.); People v. Castro, 545 N.Y.S.2d 985 (Sup. Ct. 1989) (DNA-Print evidence admitted after *Frye* hearing held over 12-week period; defendant pleaded guilty before trial); People v. Gonzalez, N.Y.L.J., Aug. 18, 1989, at 22, col. 2 (County Ct. 1989) (court holds that DNA typing evidence satisfies *Frye* test, although defendant pleaded guilty); People v. Lopez, N.Y.L.J., Jan. 6, 1989, at 29, col. 1 (Sup. Ct., Jan. 5, 1988) (evidence of DNA-Print matching DNA from semen to the DNA of defendant's blood was admitted after evidentiary hearing; defendant was convicted of rape, sodomy, sexual abuse, burglary, robbery, and unlawful imprisonment); People v. Huang, 546 N.Y.S.2d 920 (County Ct. 1989)

If the DNA specimen is found to be of a sufficiently high molecular weight—which ultimately depends upon the substance, the amount of the specimen, the extent to which it was subject to environmental factors including the length of time it was exposed, and the subsequent storage conditions—DNA typing can be done on whole blood, dried blood, sperm, bone, organs, tissue, hair roots, tooth pulp, amniotic fluid, an aborted fetus, vaginal swabs, and semen stains.[157] With less frequency, DNA typing may be done on urine, saliva and sweat; the test usually cannot be done on feces, hair with no roots, red blood cells, or dead skin.[158]

DNA typing also offers certain advantages over traditional serological tests for identifying biological samples. It has the potential to yield more

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(DNA Fingerprinting of defendant's blood is admissible evidence; scientific reliability of evidence submitted to jury as going to weight of evidence); People v. Wesley, 140 Misc. 2d 306, 533 N.Y.S.2d 643 (County Ct. 1988) (after *Frye* hearing, evidence admitted to show DNA from bloodstain found on defendant's clothing matched the DNA from the deceased victim; defendant convicted of burglary and murder charges); People v. Bailey, 140 Misc. 2d 306, 533 N.Y.S.2d 643 (County Ct. 1988) (DNA Fingerprinting evidence admitted after *Frye* hearing to show DNA from aborted fetus matched DNA from the defendant charged with first-degree rape; defendant subsequently pleaded guilty before trial), *aff'd*, 549 N.Y.S.2d 846 (App. Div. 1989); State v. Reynolds, 6 Va. App. 157, 367 S.E.2d 176 (1988) (test admitted in murder case after an evidentiary hearing); State v. Bethune, No. 492939 (Harris City Dist. Ct. Nov. 1989); State v. Cauthron, No. 88-1-1-012533 (Wash. Super. Ct. Jan. 18, 1989).

See also State v. Pioletti, No. 87-2017 (Wichita, Kan. May 9, 1988), discussed in Michaud, *supra* note 16, at 88-89 (defendant, a mortuary worker who was accused of murdering his estranged wife and then partially incinerating her at the mortuary crematorium, convicted of first-degree homicide and kidnapping after DNA-Print test matched blood stain found on oven with DNA in her remains), *aff'd*, No. 62485 (Kan. Jan. 19, 1990) (WESTLAW, Allstates library). *But see* State v. Pennell, No. 88-12-0051 (Del. Super. Ct. Sept. 25, 1989) (on motion in limine, allele probability evidence excluded since potential prejudice effects of frequency probability clearly outweighs their probative value), *aff'd*, 567 A.2d 423 (Del. 1989).

Other relevant cases included State v. Jones, No. 87-1695-CF-M (Putnam County, Fla. Mar. 23, 1988) (in first capital case using DNA typing, defendant was convicted of murder, robbery, and sexual assault and received the death sentence); State v. McCarthy, No. 87CRS5081 (Duplin County Ct., N.C. Mar. 1988) (defendant convicted of incest in first criminal case in which paternity test using DNA Fingerprinting was admitted into evidence); State v. Dascenzo, No. 88-CR-1057 (Montgomery County Ct. July 23, 1988) (after evidentiary hearing, DNA-Fingerprinting evidence was admitted in murder trial; defendant convicted) (information on all cases supplied by Cellmark); State v. Ford, No. 88-65-2245 (Georgetown, S.C. Apr. 1988) (DNA-Print evidence admitted uncontested in rape case; defendant convicted) (information supplied by Lifecodes); Commonwealth v. Johnson, No. K056096 (Fairfax County Cir. Ct., Va. Aug. 22, 1988) (DNA Fingerprinting evidence admissible in evidentiary hearing; defendant pleaded guilty a day later).

157. *See* CELLMARK DIAGNOSTICS LITERATURE, *supra* note 5, at E-3; LIFECODES BACKGROUND INFORMATION, *supra* note 6, at D-4.

158. *Id.*

specific results than traditional tests for typing blood, such as ABO typing, human leukocyte antigen (HLA) typing, or typing of red-cell enzymes and serum proteins;[159] while these biochemical identification tests compare some cellular expression of information of the DNA, DNA typing examines the DNA itself. DNA typing may be possible with smaller samples than required for many serological tests and since DNA is stronger than blood enzymes and proteins, DNA tests are likely to be less susceptible to adverse environmental conditions.[160] In addition, DNA lasts longer than other biological materials. DNA was recovered from a Florida spring and revealed brain matter 7000 years old; through PCR technology, traces of the genetic material were copied to help identify an ancient American.[161]

D. Limitations

The goal of DNA typing is to differentiate between DNA samples taken from various sources, a difficult endeavor because even though no two individuals have identical DNA, the similarities far outnumber the differences.[162] Although a finding that two samples have the same DNA typing is considerable evidence that they have a common source, the evidence is nonetheless probabilistic, not conclusive.[163] The power of identity that is obtainable depends on a number of factors, one of which is the number of probes applied. A single probe might produce a pattern unique to one person in a hundred. The use of a second probe of equally discriminating power might raise that probability to one in one thousand. Every additional probe increases the power of identity. The likelihood of a coincidental misidentification through DNA typing also depends, in part, on the validity of the underlying theories, the reliability of each step in

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159. One commentator has stated:

> Traditional lab tests of blood specimens are impossible when they have dried and aged, while DNA molecules still can be detected in dried specimens. Traditional semen testing relies on finding antigens in the semen, which are protein materials found in blood. If a person is a "non-secretor" the test cannot be done. No antigens are required to perform a DNA test on semen. The traditional HLA . . . blood test has an exclusion rating of only 90 to 95 percent . . . and, for some common blood types, the exclusion rating is as low as 50 percent.

Moss, *supra* note 19, at 66-67. For an in-depth analysis of blood typing, see Jonakait, *Will Blood Tell? Genetic Markers in Criminal Cases*, 31 EMORY L.J. 833 (1982).

160. Moss, *supra* note 19, at 66.

161. Schmeck, *supra* note 131.

162. Thompson & Ford, *supra* note 4, at 58.

163. *Id.* at 62.

the process, the accuracy of the statistical computations, and the expertise of the technicians.[164]

The PCR test is probably the most susceptible to possible error or "false positives."[165] It does offer the advantage over DNA Fingerprinting and DNA-Print Identification of being able to test very minute traces of DNA; in theory, because the PCR techique replicates the DNA, all that is required is one sperm head.[166] However, precisely because it is so sensitive, the PCR test is more susceptible to contamination from other sources or bacterial invasion.[167] Lifecodes and Cellmark both claim there are absolutely no chances for a "false positive" result in their tests; if the DNA in the sample is too degraded, the test simply does not produce a result.[168] Furthermore, the companies assert that they have extensive control measures to ensure that the process is working correctly.[169]

There are several ways in which DNA typing may produce misindentification. First, two people may have an identical DNA type; two unrelated people may have identical prints because they have polymorphic DNA segments of the same length or have the same alleles.[170] However, "[s]uch a coincidence is unlikely where a multi-locus probe is used, because each of the approximately [fifteen] bands on the [two] DNA fingerprints would have to match by chance."[171] Second, "two matching bands from different autoradiographs might consist of entirely different fragments which happen to be of the same length . . . [and] bands within the same autoradiograph may consist of different fragments having the same length."[172] "Third, fragments which are very close together in size may obscure each other's autoradiograph bands."[173] All these complexities require a high degree of technical expertise in the interpretation of the results of the autorad. The

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164. *Id.* at 63. For an in-depth discussion of the limitations of DNA typing, see generally Thompson & Ford, *supra* note 7.

165. Thompson & Ford, *supra* note 4, at 62.

166. *Id.* at 67.

167. *Id.* at 64 ("Contamination is also a special problem where polymerase chain reaction is used to 'amplify' DNA in a small specimen. The danger is that the procedure will amplify a contaminant rather than DNA from the specimen. Such an error, if it occurred, would be difficult to catch.").

168. *See, e.g.*, LIFECODES BACKGROUND INFORMATION, *supra* note 6, at 6.

169. Hearing, *supra* note 5 (statements of Robert Shaler, Ph.D., Director of Forensic Science, Lifecodes, and Dr. Daniel Garner, Director of Operations, Cellmark).

170. *See* Thompson & Ford, *supra* note 4, at 64.

171. *Id.*

172. Burk, *supra* note 5, at 465.

173. *Id.*

technician must consider the number of bands on which there is a match and the rarity of the matching bands. Some bands may be very faint or correspond to a very heavy band when the patterns are compared; these bands must be disregarded.[174] Some bands may appear in all autorads, and these too are useless for identification and must be disregarded. In addition, a degree of human judgment enters the test when the autorads are interpreted.

> [An] expert who insists that DNA prints be identical in all respects before declaring that they match, will miss a lot of matches. . . . Because two prints from the same person may not correlate perfectly, however, the cutoff point for declaring a match must be at some level short of a perfect correlation.[175]

Contamination of samples may also affect the reliability of DNA typing. If the sample taken from the crime scene or from crime-related material is contaminated with the suspect's DNA, that specimen may produce an artificial match.[176] Contamination may also occur in the laboratory, especially when small samples are analyzed. Some commentators also question the probabilities upon which DNA tests rely. "The total probability of two patterns matching by chance is dependent upon the frequency with which each individual band occurs in the population. The extensive data necessary to accurately assess the frequency of a given band in the general population—or an ethnic subpopulation—is not yet available."[177] Also, the effects of chemotherapy on DNA, the degree of relatedness between the individuals in the test, and mutations—unequal crossing over—occuring in the DNA may have an impact upon the reliability of the test.[178]

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174. *Id.*

175. Thompson & Ford, *supra* note 4, at 63-64.

176. *Id.* at 64.

> Although contamination can be controlled through the use of careful laboratory procedures, the problem has proved vexing to molecular biologists in research laboratories. An article coauthored by Dr. Robert Gallo, one of America's preeminent medical researchers, and published in a leading scientific journal, had to be retracted when it was belatedly discovered that DNA cross-contamination of experimental samples had produced spurious results. If this problem can fool a distinguished scientist like Gallo, it might trip up some forensic experts as well.

Id.

177. Burk, *supra* note 5, at 466.

178. *Id.* at 466-70.

III. EVIDENTIARY ADMISSIBILITY

In evaluating the admissibility of novel scientific evidence,[179] the courts are split on the question of what legal standard should control that inquiry and determination.

A. The Frye Standard

In a majority of states, novel scientific evidence[180] is accorded special treatment with respect to its admissibility; it must meet a threshold requirement of reliability.[181] This standard was first articulated in *Frye v.*

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179. For an in-depth analysis of the admissibility of scientific evidence, see A. MOENESSENS & F. INBAU, SCIENTIFIC EVIDENCE IN CRIMINAL CASES (2d ed. 1978); P. GIANNELLI & E. IMWINKELRIED, SCIENTIFIC EVIDENCE (1986); *see also* Giannelli, *The Admissibility of Novel Scientific Evidence; Frye v. United States, a Half-Century Later*, 80 COLUM. L. REV. 1197 (1980) (rejects substantive test of *Frye*, proposes enhanced burden for proof of reliability); Note, *Novel Scientific Evidence: Does Frye Require that General Acceptance Within the Scientific Community be Established by Disinterested Scientists*, 65 U. DET. L. REV. 147 (1987) (review of dissent in People v. Young, 425 Mich. 470, 391 N.W.2d 270 (1986)) [hereinafter Note, *Novel Scientific Evidence*]; Note, *United States v. Downing: Novel Scientific Evidence and the Rejection of Frye*, 1986 UTAH L. REV. 839 (new standard in harmony with current liberalization of rules) [hereinafter Note, *United States v. Downing*]; Note, *The Frye Doctrine and Relevancy Approach Controversy: An Empirical Evaluation*, 74 WASH. L. REV. 1769 (1986) (empirical evidence supports relevancy approach). For analyses of the standards as applied to DNA and blood typing in general, see Thompson & Ford, *supra* note 7; Note, *DNA Typing: A New Investigation Tool*, 1989 DUKE L.J. 474; Comment, *supra* note 18; Note, *The Admissibility of Electrophoretic Methods of Genetic Marker Bloodstain Typing Under the Frye Standard*, 11 OKLA. CITY L. REV. 773 (1986); Note, *supra* note 35.

180. Novel scientific evidence is derived from newly developed scientific principles or application of those principles. In the case of DNA typing, the underlying scientific principles are not considered novel; the forensic application of the technology is. Once the novel scientific evidence has been accepted as generally reliable, the next step is usually judicial notice of that technique. *See* Giannelli, *supra* note 179, at 1202-03 ("Once a technique is sufficiently established, a court may take judicial notice of the principle and the technique, thereby relieving the offering party of the burden of producing evidence on these issues. The principles underlying radar, intoxication tests, fingerprints, firearms identification, and handwriting comparisons have all been judicially recognized in this fashion.") (footnotes omitted).

181. *Id.* at 1200-02.

> For evidence to contribute to the truth-determining function of a trial, it must be reliable. The reliability of evidence derived from a scientific principle depends upon three factors: (1) the validity of the underlying principle, (2) the validity of the technique applying that principle, and (3) the proper application of the technique on a particular occasion. This last factor requires an examination of the condition of any instrumentation employed in the technique, adherence to proper procedures, the qualifications of the person conducting the procedure, and the qualifications of the person interpreting the result. . . .
>
> The first two factors — the validity of the underlying principle and the validity of the technique — are critical only with regard to the admissibility of evidence

United States,[182] which requires that the scientific principle be generally accepted "in the particular field in which it belongs."[183]

> Despite recent criticism, which has led to limitations, modification, and rejection of the *Frye* rule by some courts, the standard survives as a special rule governing the admissibility of novel scientific evidence in approximately two-thirds of United States jurisdictions. In these states, however, the rule is frequently applied amid controversy regarding what evidence must meet the standard, what methods will be used to determine acceptability, and who must find the principle or technique acceptable.[184]

The *Frye* standard ultimately seeks to differentiate between scientific evidence which has been clearly demonstrated as reliable through evaluation by scientists in the field in which the technology belongs, and scientific evidence which either has not passed the "experimental" stage,[185] or has

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derived from the novel scientific technique . . . .

Id. (footnotes omitted).

The third factor — the proper application of the technique on a particular occasion — usually applies to the weight accorded the evidence by the jury, not its admissibility.

Validity and reliability have distinct meanings. Validity refers to the accuracy of the test, while reliability refers to its consistency. *Id.* at 1201 n.20. Proof of reliability may be established by expert testimony, scientific and legal writings, and judicial opinions. *Id.* at 1215.

182. 293 F. 1013 (D.C. Cir. 1923).

183. *Id.* at 1013. In ruling on the admissibility of a systolic blood pressure deception test (a precursor to the modern polygraph), the District of Columbia Circuit formulated the evidentiary standard:

> 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.

Id. at 1014; *see also* Reed v. State, 283 Md. 374, 382-83, 391 A.2d 364, 368 (1978) (citing 27 other state courts to support its proposition that the *Frye* test "has come to be the standard in almost all of the courts in the country which have considered the question of the admissibility of scientific evidence."); People v. Kelly, 17 Cal. 3d 24, 549 P.2d 1240, 130 Cal. Rptr. 144 (1976) (*Frye* test used to reject voice-print evidence); Giannelli, *supra* note 179, at 1205.

184. Note, *Novel Scientific Evidence*, *supra* note 179, at 148 (citation omitted).

185. As one commentator noted:

> *Frye* envisions an evolutionary process leading to the admissibility of scientific evidence. A novel technique must pass through an "experimental" stage in which it is scrutinized by the scientific community. Only after the technique has been tested successfully in this stage and has passed into the "demonstrable" stage will

not been sufficiently demonstrated as reliable. Theoretically, the *Frye* standard would ensure that the former evidence is admissible while the latter would be excluded.

The proponents of the *Frye* standard would offer various arguments in its support,[186] the most substantial justification being that it provides a workable "*method* for ensuring the reliability for scientific evidence."[187] The necessity of a valid method of examining scientific evidence becomes acute when the evidence involves highly technical and complicated technologies. In that instance, courts and juries might rely more on the testimony of experts and be predisposed to place greater weight on it.[188] Incorporating the *Frye* standard into practice, however, has presented many difficulties to courts confronted with novel scientific evidence.[189] The areas of conflict most often encountered are delineating the particular field(s) in which the novel scientific evidence belongs, defining the parameters of general acceptance, and the method by which general acceptance is established.[190]

Deciding the appropriate field in which the scientific technology belongs is frequently difficult because an integration or combination of various disciplines are often involved.[191] An illustration of this difficulty

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it receive judicial recognition.

Giannelli, *supra* note 179, at 1205.

186. *See*, Note, *United States v. Downing*, *supra* note 179, at 840.

> [P]roponents of *Frye* claim that the general acceptance standard (1) guarantees the existence of experts qualified to testify about particular techniques and promotes uniformity of decisions; (2) safeguards against the possible prejudicial effects of testimony based on an unproven hypothesis in an isolated experiment; and (3) eliminates the need for time consuming hearings on the validity of innovative techniques.

Id. (footnotes omitted); *see also* United States v. Addison, 498 F.2d 741, 743-44 (D.C. Cir. 1974) ("The requirement of general acceptance in the scientific community assures that those most qualified to assess the general validity of a scientific method will have the determinative voice."); People v. Barbara, 400 Mich. 352, 405, 255 N.W.2d 171, 194 (1977):

> It therefore is best to adhere to [the *Frye*] standard which in effect permits the experts who know most about a procedure to experiment and to study it. In effect, they form a kind of technical jury, which must first pass on the scientific status of a procedure before the lay jury utilizes it in making its findings of fact.

Id. (citation omitted).

187. Giannelli, *supra* note 179, at 1207 (emphasis in original).

188. *See* Note, *supra* note 35, at 933 n.155 ("A strict standard of general acceptance is appropriate with complex scientific procedures because the jury is likely to accept them without critical scrutiny.").

189. *See* Note, *United States v. Downing*, *supra* note 179, at 840-41 (footnotes omitted) ("Difficulties in defining [the *Frye* standard's] terms have permitted courts to manipulate its parameters, subverting the uniformity of decision paradigm for which *Frye* has been hailed.").

190. *See* Giannelli, *supra* note 179, at 1208.

191. *See, e.g., id.* at 1208 n.68:

appears in a case on DNA typing in New York, *People v. Wesley*.[192] In an evidentiary hearing on the admissibility of the test, the court determined that DNA typing embraced the scientific fields of molecular biology, genetics, and a specialized branch of genetics known as population genetics.[193] Yet, in concluding, the court stated that "the particular fields . . . in which [DNA typing] belongs [are] molecular biology, population genetics and diverse other branches of genetics, chemistry, biology, and biochemistry."[194] Evidently, the court envisioned DNA typing as involving many scientific fields, but nevertheless narrowed those fields to the three most relevant "subspecialties" with respect to its inquiry. The court in *Wesley*, at least implicitly, utilized the standard adopted in *People v. Williams*,[195] that general acceptance can be established "by those who would be expected to be familiar with its use."[196] Such an approach is not in itself inconsistent with the *Frye* standard, however "if the 'specialized field' is too narrow, the consensus judgment mandated by *Frye* becomes illusory, the judgment of the scientific community

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> Deciding what is the proper field to which a novel test belongs is in itself a chore. Most novel tests represent new approaches to the solution of old problems by a process which is unknown, or belongs to a different field. Because of this, the person developing a novel test frequently finds himself on the fringes of his scientific discipline, and perhaps overlapping into disciplines.

Id. (citation omitted); *see also* Jonakait, *supra* note 159, at 844:

> The test has been characterized as vague and therefore difficult to apply. One court has stated that the *Frye* standard "is usually construed as necessitating a survey and catergorization of the subjective views of a number of scientists . . . but a determination of reliability cannot rest solely on a process of counting (scientific) noses."

Id. (footnote omitted) (quoting United States v. Williams, 583 F.2d 1194, 1198 (2d Cir. 1978)).

192. 140 Misc. 2d 306, 533 N.Y.S.2d 643 (County Ct. 1988).

193. *Id.* at 309, 533 N.Y.S.2d at 645.

194. *Id.* at 332, 533 N.Y.S.2d at 659. As one commentator explained:

> Biochemistry is a broad field concerning the chemistry of living creatures, and so includes investigation of the DNA molecule. Molecular biology primarily concerns the study of nucleic acid structure and function; it is sometimes considered a subspecially of biochemistry. Biochemists in general, and molecular biologists in particular, often use the techniques employed in DNA fingerprinting.

Burk, *supra* note 5, at 468 n.58.

195. 164 Cal. App. 2d Supp. 858, 331 P.2d 251 (Super. Ct. 1958).

196. *Id.* at 862, 331 P.2d at 254. DNA typing presents a particularly complex problem for the courts. As one commentator explained:

> Scientific techniques that do no fall within a single field present the most difficulty in determining the field to which the underlying principle belongs. Many novel techniques combine elements of several disciples. Courts are then forced to decide whether the principle must be generally accepted within all involved fields or by a single field that appears to have dominant interest.

Note, *Novel Scientific Evidence*, *supra* note 179, at 155.

becomes, in reality, the opinion of a few experts."[197]

The delineation of the scientific community has a significant impact on the consideration of whether the scientific technique has been generally accepted by its members.[198] For instance, if the scientific fields involved in DNA typing were deemed to be molecular biology, population genetics, and "diverse other branches of genetics, chemistry, biology, and biochemistry" it would be difficult to conclude that DNA typing is generally accepted by the members of those fields. This result is necessitated, in part, because the majority of those scientists are not involved in the forensic application of the technique. If the field is narrowed and general acceptance is further defined as requiring relative consensus among those who are familiar with the technique, then general acceptance is more easily obtainable.

> Although it is generally agreed that *Frye* does not require unanimous acceptance, a consensus on whether a certain percentage of those in the field must accept the technique has never been achieved. Most courts define the standard generally, rather than quantitatively, or ignore the issue altogether. Either view may allow the admission of evidence derived from a principle or technique that is unacceptable to a large portion of the scientific community.[199]

General acceptance may be established in several ways: through other judicial opinions recognizing the admissibility of the novel technology, through scientific and legal publication, and through expert testimony from the relevant scientific community.[200] While DNA typing has been available only since 1987, it has been admitted in more than two hundred criminal trials in about twenty-seven states, and that number is increasing exponentially.[201] A problem may arise, however, if a trial judge, in a hearing on the admissibility of the DNA Fingerprint test, takes judicial notice of evidence presented in a case involving the DNA Print test.[202] While it may be appropriate for courts to judicially recognize expert testimony in other cases, it is questionable whether it is appropriate when the inquiries in each case involve different DNA typing tests. The DNA Print test and the DNA Fingerprint test do involve essentially similar

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197. Giannelli, *supra* note 179, at 1209-10 (footnote omitted).

198. *Id.* at 1208 ("selection of the appropriate field may be dispositive") (citing United States v. Williams, 583 F.2d 1194, 1198 (2d Cir. 1978) ("selection of the 'relevant scientific community', appears to influence the result."), *cert. denied*, 439 U.S. 1117 (1979)).

199. Note, *Novel Scientific Evidence*, *supra* note 179, at 155-56.

200. Giannelli, *supra* note 179, at 1215-19.

201. *See supra* note 156.

202. Hearing, *supra* note 5 (statement of Steve Hogan, Rensselaer County District Attorney, Troy, New York).

scientific methods, but differ greatly in the type of probes used and therefore their mean power of identity.[203]

General acceptance may also be established by scientific or legal publication and expert testimony. Since forensic application of the technology is in its infancy, publications on DNA typing are almost exclusively in scientific journals, none of which question the underlying principle or the technology. This fact is mentioned often in the cases concerning DNA typing.[204] Hence, it is clear that at this point the reliability of DNA typing rests primarily on the testimony of expert witnesses.

B. *The Relevancy Approach*

Given the difficulties presented by the *Frye* standard,[205] many jurisdictions have embraced the relevancy approach,[206] which treats novel scientific evidence

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203. See *supra* notes 97-101 and accompanying text for a discussion of the different probes used in these tests.

204. *See* People v. Wesley, 140 Misc. 2d 306, 326-27, 533 N.Y.S.2d 643, 656 (County Ct. 1988); Andrews v. State, 533 So. 2d 841, 849-50 (Fla. Dist. Ct. App. 1988).

205. There is sometimes much confusion on exactly what standard is followed in a certain jurisdiction. *See Andrews*, 533 So. 2d at 843 ("We begin by confessing some uncertainty as to the standard applicable in this state governing admissibility into evidence of a new scientific technique."). Sometimes courts engraft their own interpretive language. *See, e.g.*, People v. Williams, 164 Cal. App. 2d Supp. 858, 862, 331 P.2d 251, 254 (Super. Ct. 1958) (court upheld the admissibility of the Nalline test for detecting narcotic use because the test had "been generally accepted by those who would be expected to be familiar with its use"); Commonwealth v. Lykus, 367 Mass. 191, 204 n.6, 327 N.E.2d 671, 678 n.6 (1975) ("[t]he *Frye* standard does not require unanimity of view, only general acceptance; a degree of scientific divergence of view is inevitable."). Sometimes a court will seem to ignore the test completely. *See, e.g.*, Coppolino v. State, 223 So. 2d 68, 70 (Fla. Dist. Ct. App. 1968), *appeal dismissed*, 234 So. 2d 120 (Fla. 1969) (trial court's admission of results of a scientific test developed specifically for the trial was upheld because it was not an abuse of discretion, not on *Frye* grounds), *cert. denied*, 399 U.S. 927 (1970); United States v. Ridling, 350 F. Supp. 90, 94 (E.D. Mich. 1972) (decisions of state and federal courts excluding polygraph testimony predicated on unreliability of polygraph were entitled to great weight in determining whether to admit polygraph testimony in perjury prosecution, but were not persuasive in view of improvements in technology and technique).

206. The relevancy approach is usually associated with Professor McCormick and is similar to the balancing test codified in Rule 403 of the Federal Rules of Evidence. Relevant evidence should be admitted unless its prejudicial effect is deemed to outweigh its probative value. The question of unreliability or lack of acceptance in the scientific community goes to the weight of the evidence rather than its admissibility. McCormick wrote:

> [The relevancy approach] permits general scientific opinion of both underlying principles and particular applications to be considered in evaluating the worth of the testimony. In so treating the yeas and nays of the members of a scientific discipline as but one indication of the validity, accuracy, and reliability of the technique, the traditional balancing method focuses that court's attention where it belongs — on the actual usefulness of the evidence in light of the full record

similarly to other types of evidence: it must be relevant, it must not be substantially prejudicial or misleading to the jury as to outweigh its relevance, and its reliability must be testified to by an expert.[207]

> 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 probable or less probable than it would be without the evidence." . . . The probative value of scientific data, however, is connected inextricably to its reliability; if the technique is not reliable, evidence derived from the technique is not relevant.[208]

Thus, especially when a highly technical novel scientific procedure is being evaluated, the relevancy approach envisions the use of scientific expert testimony to establish reliability.[209] However, the method by which that reliability is established, the level of acceptance that is required for reliability, and the degree of expert testimony needed involve essentially the same problems found under the *Frye* standard.[210]

Without having gained widespread or even minimal acceptance in

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> developed on the power of the scientific test. Furthermore, unlike the general or the substantial acceptance standards, it is sensitive to the perceived degree of prejudice and unnecessary expense associated with the scientific technique in issue.

C. MCCORMICK, EVIDENCE § 203, at 609 (3d ed. 1984); *see also* Giannelli, *supra* note 179, at 1232-43; Note, *Novel Scientific Evidence*, *supra* note 179, at 150.

207. Giannelli, *supra* note 179, at 1233 (citing Coppolino v. State, 223 So. 2d 68 (Fla. Dist. Ct. App. 1968), *appeal dismissed*, 234 So. 2d 120 (Fla. 1969), *cert. denied*, 399 U.S. 927 (1970)).

208. *Id.* at 1235 (footnotes omitted).

209. *See* Note, *DNA Identification Tests*, *supra* note 35, at 935 ("Because the Federal Rules of Evidence require that the basis for expert testimony be reasonably relied upon by qualified experts, the [relevancy approach], like the *Frye* test, requires some degree of scientific acceptance of novel scientific techniques."); *see also* Giannelli, *supra* note 179, at 1236 n.299:

> Like the *Frye* standard, the relevancy approach depends on the quality of expert testimony. A court's failure to impose a demanding standard on the qualifications of experts, however, is more important under the relevancy approach, because the stringent requirements of *Frye* no longer provide a backstop to admissibility. . . . [T]he trial judge is given considerable leeway in determining the qualifications of experts, and his decision will be reversed only for an abuse of discretion. Unfortunately, this means in many cases that the "standards applied are often quite loose."

Id. (citations omitted) (quoting Korn, *Law, Fact, and Science in the Courts*, 66 COLUM. L. REV. 1080, 1084 (1966)).

210. See *supra* notes 180-206 and accompanying text for a discussion of the difficulties presented by the *Frye* standard.

the relevant scientific community, novel scientific evidence may be considered reliable only as long as its reliability is otherwise established.[211] In *Andrews v. State*,[212] the first case involving DNA typing to reach an appellate court, admissibility of the test was determined under the relevancy approach.[213] While no experts testified for the defense, several experts testified for the state, including a biologist, a forensic scientist employed by the company offering the test, and a geneticist who managed the laboratory at the company offering the test.[214] The defense questioned the "built-in bias" of the latter two witnesses "because their reputations and careers are built on DNA comparison work,"[215] but the court pointed out that "[neither] *Frye* nor our evidence code require impartiality,"[216] and that "DNA comparison work has a number of uses in fields other than forensic medicine such as diagnosis and treatment of diseases."[217] The perceived need for impartial expert witnesses has been an on-going debate under the relevancy approach as well as the *Frye* standard,[218] but the *Andrews* court obviously was not concerned with the fact that two of the three witnesses who testified had a pecuniary interest in seeing the test meet the evidentiary standard.

The *Andrews* court found the fact that there was "extensive nonjudicial use of the test,"[219] that "a great many scientific works exist regarding DNA identification,"[220] and the infrequency of erroneous results dispositive of the reliability issue . The court ruled that while "the scientific evidence here . . . is highly technical, incapable of observation, and requires the jury to either accept or reject the scientist's conclusions that it can be done,"

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211. *See* Andrews v. State, 533 So. 2d 841 (Fla. Dist. Ct. App. 1988). There, Judge Orfinger stated:

> [U]nder the relevancy approach where a form of scientific expertise has no established "track record" in litigation, courts may look to other factors which bear on the reliability of the evidence. One of these is the novelty of the technique, i.e., its relationship to more established modes of scientific analysis.
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> . . . .
>
> Another factor is the existence of specialized literature dealing with the technique. . . . A further component of reliability is the frequency with which a technique leads to erroneous results.

Id. at 849-50 (citations omitted).

212. 533 So. 2d 841 (Fla. Dist. Ct. App. 1988).

213. *Id.*

214. *Id.* at 847.

215. *Id.* at 849 n.9.

216. *Id.*

217. *Id.*

218. *See* Note, *Novel Scientific Evidence*, *supra* note 179.

219. *Andrews*, 533 So. 2d at 849.

220. *Id.* at 850.

DNA typing appears to be based on proven scientific principles.[221]

Whichever standard is used in determining the admissibility of DNA typing evidence, there are a number of concerns applicable to both: (1) under either standard it is not always true that the evidence eventually admitted is necessarily reliable;[222] (2) the burden of showing that the evidence is not reliable is often shifted onto the defendant;[223] (3) the ensuing "battle of the experts" does not in and of itself guarantee that all relevant facts on the issue are brought forth;[224] and (4) it is not certain whether the members of the jury can adequately evaluate the content of the scientific technology.[225]

IV. CONSTITUTIONAL IMPLICATIONS

The standards and procedures created for the admission of novel scientific evidence were clearly designed with the intention that the evidence presented be clearly reliable and accurate. However, since those standards are not always sufficient to insure reliability and since there is a burden placed upon the defendant to demonstrate unreliability, the remaining question is what effect those facts have upon the defendant's right to a fair trial.

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221. *Id.*

222. For instance, the paraffin test, which was designed to detect gunshot residue on the hand of a person who had recently fired a gun, was admitted unchallenged under the *Frye* standard in 1936, despite commentary questioning its reliability. It was not until 1967 that the test was eventually repudiated as unreliable. Under the *Frye* standard it had been widely used, and deemed generally accepted, but it was not reliable. Giannelli, *supra* note 179, at 1224-25. *See also* Jonakait, *supra* note 159, at 843-57 (*Frye* standard is insufficient to ensure reliability).

223. *See* Jonakait, *supra* note 159, at 857-72. Most criminal defendants cannot afford to provide expert testimony to counter the prosecution's showing of scientific technique reliability. In addition, a defendant may not have the same access to the laboratories as the prosecution. Even if the defendant can afford experts, he will often have difficulty finding disinterested experts in the very narrow scientific field of DNA typing. *Id.* at 861-62.

224. Theoretically, the adversary system is designed to present all sides of a particular issue. Thus, when a new scientific technology is the issue, the prosecution presents its own expert witnesses to defend the technique, and the defendant presents expert witnesses to challenge the technique. But the defendant usually does not have the resources to challenge the evidence by presenting high caliber, highly qualified expert witnesses. The defendant frequently must rely on cross-examinations of the prosecution's expert witnesses. Presentation of necessary scientific data, therefore, may be somewhat skewed in favor of the scientific evidence sought to be introduced.

225. *See* Giannelli, *supra* note 179, at 1237 ("The major danger of scientific evidence is its potential to mislead the jury; an aura of scientific infallibility may shroud the evidence and thus lead the jury to accept it without critical scrutiny.").

A. Fourth and Fifth Amendments

At the outset, it is clearly established that the taking of a biological sample from a defendant involves no violation of his fourth amendment right against unreasonable searches and seizures,[226] nor his fifth amendment right against self-incrimination.[227]

Schmerber v. California,[228] the leading case involving the removal of bodily evidence, stands for the proposition that "the [f]ourth [a]mendment's proper function is to constrain, not against all intrusions as such, but against intrusions which are not justified in the circumstances, or which are made in an improper manner."[229] The *Schmerber* court held that the taking of a blood sample for purposes of chemical analysis was not an unreasonable search and seizure in violation of the fourth amendment.[230]

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226. The fourth amendment provides in part: "The right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated . . . ." U.S. CONST. amend. IV. This prohibition is applicable to the states through the fourteenth amendment. Mapp v. Ohio, 367 U.S. 643 (1961).

There are, however, significant fourth amendment privacy concerns involved in DNA typing. These concerns relate more specifically to the issue of setting up a DNA database which is beyond the scope of this Note. It should be noted, however, that the probes used in DNA testing are created merely to seek out the polymorphic regions in the DNA that as yet have no known function. *See supra* text accompanying notes 60-66. Thus, it has been asserted that DNA testing does not reveal any information that would involve an individual's privacy. However, medical science does have the present capability to design probes to seek out certain genetic abnormalities or other sensitive and highly private information about the content of one's DNA. It is conceivable, therefore, that the test could be used for that purpose as well.

> Ultimately, the FBI lab and others around the country expect to be able to reconstruct a descriptive physical profile of a criminal including hair and eye color by unlocking the genetic codes hidden in specimens as small as a hair or a drop of blood. . . . .
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> There are five billion pairs of nucleotides in a person's DNA make up. . . . [T]hree pair determine the color of hair, three pair determine the color of eyes. [It is] just a matter of time until we find the pairs to draw a physical profile of a person just from their DNA.

Malcolm, *supra* note 8, at 1, col. 4-5. Because of the potential to use DNA typing for information about a person's genetic configuration and predisposition to specific diseases, as well as the future potential to use DNA typing as a means to read information on a person's polymorphic regions within the DNA, the privacy and civil libertarian concerns are very real and very serious. "There is no system for maintaining secrecy that has not been violated . . . ." Nance, *supra* note 35, at 25, col. 6. Thus, DNA databases present significant privacy concerns. *See* Shapiro, *supra* note 16, at 1, col. 5.

227. The fifth amendment privilege against self-incrimination is limited to evidence of a testimonial or communicative nature. *See, e.g.*, Schmerber v. California, 384 U.S. 757, 761 (1966).

228. *Id.*

229. *Id.* at 768.

230. *Id.* at 772. The method by which biological samples must be taken, however, is

B. Right to Expert Services

> 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. Nevertheless, a surprising number of novel techniques have gained admissibility without the presentation of defense expert testimony.[231]

Indeed, in at least three cases in jurisdictions not presented previously with DNA typing evidence, the evidence was admitted uncontested.[232] The fundamental problem is that:

> "the burden of rebuttal is generally borne in these criminal cases by defendants without the economic means to marshal scientific witnesses for a battle of the experts." In contrast, the prosecution has ready access to expert witnesses and laboratory facilities. All states and most large metropolitan areas have government-operated forensic laboratories.

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subject to constitutional scrutiny. The Court in *Schmerber* formulated three factors to evaluate the reasonableness of the bodily intrusion; there must be a clear indication that the desired evidence would be found; a reasonable test must be chosen that is reliable, medically routine, and virtually without risk, trauma, or pain, and, when necessary, performance of the test by a physician in a hospital environment. *Id.* at 770-71. Since it is possible for a DNA typing test to be done on hair root, a taking of that type of sample would require an even lesser bodily intrusion than the blood sample taken in *Schmerber.*

231. Giannelli, *supra* note 179, at 1243 (footnotes omitted). "In approximately eighty percent of the twenty-five [voiceprint] cases in which such expert testimony/opinion was admitted there was no opposing expert testimony on the issue of reliability and general acceptability of the scientific community. . . ." *Id.*

> Kalven and Zeisel, in their study of the American jury system, . . . noted the disparity between defense and prosecution use of expert witnesses: "Again, the imbalance between prosecution and defense appears. In 22 percent of the cases the prosecution has the only expert witness, whereas in only [three] percent of the cases does the defense have such an advantage."

Id. at 1243 n.344 (quoting People v. Chapter, 13 Crim. L. Rep. (BNA) 2479 (Cal. Super. Ct. 1973)) (citations omitted).

232. *See supra* notes 152 & 156. Even when DNA typing evidence is challenged, frequently the defense will challenge only the technique as it was applied on a particular occasion to the defendant; neither the underlying theory nor the validity or reliability of the technique applying that theory is challenged. *See* Hearing, *supra* note 5 (statement of Douglas Rutnick, Albany County Public Defenders, New York) (advocating uniform procedures, possibly by having legislatures declare test valid or licensing methodology, thus limiting possible issues on challenge to whether the test was applied properly to particular defendants). It should also be pointed out that a large percentage of defendants identified by DNA typing evidence either plead guilty or agree to a plea bargain. *See supra* notes 146-48 and accompanying text. It is tempting to conclude that these defendants therefore must be guilty of the charge. But such a generalization would be inappropriate.

> In addition, federal laboratories provide services to local and state law enforcement agencies. The FBI laboratory, for example, is "available without charge to all duly constituted state, county, and municipal law enforcement agencies of the United States and its territorial possessions." This includes both examination of evidence and the court appearances of the expert.[233]

The need for expert assistance in criminal prosecutions where DNA typing evidence will be introduced is not limited to a challenge of the admissibility of the evidence itself.[234] Once the evidence is admitted, the defendant must always challenge the evidence based on how the test was performed on his particular samples.[235] It is necessary that the defendant retain sufficient scientific experts to aid him in that challenge.[236]

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233. Giannelli, *supra* note 179, at 1244. "About half of the states and the federal government have specific provisions under which courts are authorized to provide for public compensation of defense experts. A number of other states have statutes which allow appointed counsel to recover his expenses, including, in some of these states, fees of experts." *Id.* at 1244 n.350. The Criminal Justice Act of 1964, 18 U.S.C. § 3006(A)(e) (1988) provides for such costs to federal criminal defendants.

234. Aside from establishing the validity and reliability of the underlying principle of the novel scientific evidence and the particular technique in applying that principle, the proper application of the technique on a particular occasion must be shown. "This . . . requires an examination of the condition of any instrumentation employed in the technique, adherence to proper procedures, the qualifications of the person conducting the procedure, and the qualification of the person interpreting the results." Giannelli, *supra* note 179, at 1201-02 (footnotes omitted). One purpose of the standards and procedures governing the admissibility of novel scientific evidence is to by-pass the expensive and time-consuming process of verifying the validity and reliability of the principle and the technique once those requirements have been found to be satisfied in a jurisdiction. The *Frye* hearing in the case of People v. Wesley, 140 Misc. 2d 306, 533 N.Y.S.2d 643 (County Ct. 1988), cost the state upwards of $50,000. However, now that the jurisdiction has ruled the DNA typing admissible, the evidence will be more easily admitted without the need for further hearings. What remains to be challenged at trial is the application of the test to a particular defendant.

235. Normally, at least six sets of tests must be done. For instance, in a rape case a biological substance from the victim will be tested, a biological sample containing the rapist's semen taken from the victim must be tested, and that test must be compared to a test performed on a sample provided by the defendant. To assure accuracy, these samples should be re-tested by a different laboratory. As of September 1988, Lifecodes charged $325 per sample (this price includes restriction enzyme digestion, electrophoresis, hybridization, autoradiographs, allele frequency determination and a written report), and $750 per hour for expert witnesses (information supplied by Lifecodes). As of June 1988, Cellmark charged $285 per sample, and $500 per hour for expert witnesses (information supplied by Cellmark).

236. To challenge the weight of the evidence to be accorded the DNA typing test, defense counsel must necessarily understand the theory, the technique, and the process of evaluating the results. Expert witnesses to aid the defense counsel, therefore, must have extensive knowledge of these areas. The defense counsel might need several experts to aid in the challenge to DNA typing evidence as it involves several scientific fields; molecular

An assertion of the right to expert services paid by government funds[237] has been held to be protected by the due process clause,[238] the right to compulsory process,[239] and the equal protection clause.[240] However, a majority of the decisions granting expert services are based "on the facts." The courts are reluctant to espouse flatly the right of indigent defendants to use government funds for expert services. Indeed, a majority of the state courts considering defense requests for expert witnesses or other expert services assert that there exists neither a constitutional nor an explicit statutory right within their respective jurisdictions mandating such assistance.[241]

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biology, genetics, forensic science, and population genetics (statistics). See *supra* note 185-204 and accompanying text for a discussion of the "general scientific community" in the *Frye* standard.

237. The right to expert services applies mainly to indigent defendants.

> It is important to note that while many states have statutes which reimburse appointed counsel for necessary expenses incurred in the representation of an indigent charged with crime [sic], there is no specific legislative authority for such assistance and, accordingly, the outcome of such a request is dependant upon the broad discretion of the jurisdiction's trial court judges.

Decker, *Expert Services in the Defense of Criminal Cases: The Constitutional and Statutory Rights of Indigents*, 51 CIN. L. REV. 574, 575 n.7 (1982).

238. *See* Ake v. Oklahoma, 470 U.S. 68 (1985) (due process requires state to provide access to psychiatric assistance for defendant who had made preliminary showing that sanity would be significant factor at trial, if defendant cannot afford to pay); Jacobs v. United States, 350 F.2d 571 (4th Cir. 1965) (lay testimony about petitioner's mental instability combined with testimony of government psychologist raised substantial question of indigent's mental capacity at time of trial and necessitated appointment of psychiatrist for him at government's expense). *See generally* Casey & Keilitz, *An Evaluation of Mental Health Expert Assistance Provided to Indigent Criminal Defendants: Organization, Administration, and Fiscal Management*, 34 N.Y.L. SCH. L. REV. 19 (1989) (discussing the implications of *Ake*, and the implementation of *Ake*'s requirements).

239. *See* People v. Watson, 36 Ill. 2d 228, 221 N.E.2d 645 (1966) (trial judge's refusal to provide indigent defendant with funds to obtain services of a document examiner effectively precluded him from offering defense to forgery charge). *But see* San Miguel v. McCarthy, 8 Ariz. App. 323, 446 P.2d 22 (1968) (state did not have constitutional duty to provide, at its expense, expert assistance to an indigent).

240. *See Jacobs*, 350 F.2d at 573.

241. Decker, *supra* note 238, at 574-75.

> A variety of reasons for denying constitutional or statutory claims for expert services has been offered by appellate courts over the years: (1) the defendant failed to demonstrate how he was prejudiced by the trial court's refusal to appoint an expert; (2) the defendant failed to show a need for such assistance; (3) the government's expert offered an impartial, objective assessment of the evidence; (4) the government's expert was competent; (5) the government's expert did not withhold any test results that might have been beneficial to the accused; (6) the defendant's attorney exhibited, prior to and during the trial, an intelligent understanding of the subject matter reflected in the government expert's report; (7) the defendant's attorney had full opportunity to cross-examine the government's expert vigorously; and (8) the trial court lacked power, absent legislative authority,

V. CONCLUSION

DNA typing is a fascinating and an incredibly important breakthrough in the criminal justice system's search for the quintessential identification method. Voiceprints, bitemark comparisons, handwriting analysis, and genetic marker testing, among others, have all sought to satisfy that goal with varying degrees of success. DNA typing is the latest and most successful method to date. But the criminal justice system has a higher duty — to seek the truth. It must proceed with a special degree of caution, especially when scientific evidence is sought to be used in uncharted territory. Some may regard a cautious approach as a by-product of scientific ignorance,[242] still others may regard it as healthy skepticism. Whatever the case may be, the courts and state legislatures should take a hard look at this new technology. As the use of DNA typing expands and the techniques become more widely available through other entities, such as state crime laboratories, there should be some regulatory initiative to ensure the reliability and continued accuracy of the DNA typing test. There is a conspicuous lack of critical review regarding this new technology. Perhaps it is because DNA typing is flawless. The crucial question is — what if it is not?

Jessie Jo Barr

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to furnish the defendant with an expert.

Id. at 575 (footnotes omitted).

242. Dr. David Housman, a biologist at M.I.T., has suggested that lawyers who question the accuracy of the test "don't know basic biology." However correct this assessment may be, the accuracy of the test rests primarily upon principles of physics, chemistry, and even psychology. Its admission into court rests wholly upon principles of law.

Burk, *supra* note 5, at 467 n.54 (citations omitted).