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The Dark Side of DNA Profiling:
Unreliable Scientific Evidence Meets the Criminal Defendant

Janet C. Hoeffel*

Law, including criminal law, must in a free society be judged ultimately on the basis of its success in promoting human autonomy and the capacity for individual human growth and development. The prevention of crime is an essential aspect of the environmental protection required if autonomy is to flourish. It is, however, a negative aspect and one which, pursued with single-minded zeal, may end up creating an environment in which all are safe but none is free.¹

It is time for you to gather some idea of what power means. The first thing you must realize is that power is collective. The individual has power in so far as he ceases to be an individual. . . . The second thing for you to realize is that power is power over human beings. Over the body—but, above all, over the mind. Power over matter—external reality, as you would call it—is not important. Already our control over matter is absolute.²

* * *

Big Brother is knocking on our door only six years late. “It” is not quite as George Orwell envisioned, but do not let it fool you just because it comes masked in microscopic form and speaks the impenetrable language of the allegedly infallible scientist. DNA profiling technology³ is making its entrance with the help of “Newspeak,”⁴ which

³ Although DNA profiling is better known as DNA or genetic “fingerprinting,” this note takes the view that equating the procedure with fingerprinting, a forensic technique considered so reliable that courts take judicial notice of its reliability, has contributed to the premature acceptance of DNA profiling as reliable in criminal prosecutions. See Dan L. Burk, DNA Fingerprinting: Possibilities and Pitfalls of a New Technique, 28 Jurimetrics J. 455, 468-69, 469 n.65 (1988) (noting that “the name ‘fingerprinting’ may create unsubstantiated beliefs and expectations in the minds of judges and jurors,” and recognizing that a similar problem occurred with the name “voiceprint” for sound spectrometry). In addition, the term “fingerprinting” suggests a relatively nonintrusive procedure, unlike DNA typing, which can result in lesser protection against unreasonable searches and seizures under the fourth amendment. See text accompanying notes 359-383 infra. This note may also refer to DNA profiling as DNA “typing,” “testing,” or “identification.”

² GEORGE ORWELL, NINETEEN EIGHTY-FOUR 218 (1949).
³ Although DNA profiling is better known as DNA or genetic “fingerprinting,” this note takes the view that equating the procedure with fingerprinting, a forensic technique considered so reliable that courts take judicial notice of its reliability, has contributed to the premature acceptance of DNA profiling as reliable in criminal prosecutions. See Dan L. Burk, DNA Fingerprinting: Possibilities and Pitfalls of a New Technique, 28 Jurimetrics J. 455, 468-69, 469 n.65 (1988) (noting that “the name ‘fingerprinting’ may create unsubstantiated beliefs and expectations in the minds of judges and jurors,” and recognizing that a similar problem occurred with the name “voiceprint” for sound spectrometry). In addition, the term “fingerprinting” suggests a relatively nonintrusive procedure, unlike DNA typing, which can result in lesser protection against unreasonable searches and seizures under the fourth amendment. See text accompanying notes 359-383 infra. This note may also refer to DNA profiling as DNA “typing,” “testing,” or “identification.”
touts the technique as the “greatest boon to forensic medicine and law since fingerprinting” and claims that “disputing the technology is like disputing the law of gravity.”

DNA profiling technology has limitless Orwellian possibilities, but the legal community is presently focused on the technology’s ability to identify criminal suspects. Although it usually takes many years for the engines of justice to churn out a personal injury suit or a criminal appeal, in less than two years the combined efforts of commercial laboratories and prosecutors have steamrolled the so-called “DNA fingerprinting” technique through the courts. The technique has been easy to sell. The current national obsession with crime-fighting and the apparent decrease in concern for individualized justice create a receptive environment for a cutting-edge technology, dazzling in its promise of identifying criminals with “virtual” or “99 percent certainty.” Courts lost all sense of balance and restraint in the face of this novel scientific evidence, embracing it with little scrutiny of its actual reliability and little concern for its impact on the rights of individuals.

Members of the stunned defense bar have only recently come to life to launch a serious attack on the reliability of the evidence. Unfortunately, the rather sophisticated, technical challenge by these defense attorneys may be lost on everyone in the courtroom except the scientists who are testifying. The courts and the public must be made aware of the full impact of the damage done and the precedent set as they allow prosecutors, commercial laboratories, and the media to push

4. Newspeak is the medium through which George Orwell’s “Big Brother” brainwashed individuals in Nineteen Eighty-Four. See G. ORWELL, supra note 2, at 246-56.


7. Forensic DNA testing has been employed in hundreds of criminal cases nationwide. The data from these tests has been considered as evidence in over 80 criminal rape and murder trials in 27 states, leading to at least 64 convictions or guilty pleas. Marcia Barinaga, DNA Fingerprinting: Pitfalls Come to Light, 339 NATURE 89 (1989).

8. One powerful example of this phenomenon is the new federal sentencing guidelines which virtually eliminate judicial discretion in sentencing and have the effect of creating a class of strict liability crimes in the area of drug trafficking. Federal District Court Judge Schwarzer wept openly in court when he was forced by the guidelines to sentence to 10 years in prison a man who simply gave a ride to a drug-carrying acquaintance. New Drug Law Is Backfiring, Judges Say, San Francisco Chron., Sept. 25, 1989, at A1, col. 1.

9. Moss, supra note 6, at 66 (citing claims of two leading commercial laboratories engaged in DNA profiling).

10. For instance, Moses Sanchez of Houston, Texas, who unsuccessfully defended his client against the evidence, said of the technique, “When an expert comes in and says there’s a one in 700 million chance that your man is not the one—and you know he’s one of only 30 million black men in the country—it just kills you. It intimidates the jury. The defense bar better get ready.” Gary Taylor, From One Speck, a Case is Made, Nat’l L.J., Jan. 16, 1989, at 22.

the currently unreliable and unproven DNA profiling evidence into court.

In the midst of all the cheers and exaggerations, this note presents the darker side of employing DNA profiling to identify criminals.12 Part I examines the scientific problems with the technique. It presents the underlying scientific principles, the mechanics of the technique as it is presently performed, and the flaws in the technique's application to criminal forensics which currently make it unreliable. Finally, Part I proposes that a working committee of scientists research and validate the forensic application of the technique and implement controls to ensure its reliability.

Part II examines problems with the legal standards for admitting novel scientific evidence into the courtroom as well as the impact of the admission of DNA profiling evidence on the defendant's constitutional right to an adequate defense. Three recent cases involving DNA profiling evidence will be used to illustrate the problems inherent in the present standards of legal admissibility and will demonstrate that the courtroom is an improper forum for deciding the technique's reliability. Finally, Part II proposes returning to the relevant scientific community the determination of the reliability of novel scientific techniques too complex for judges and juries to evaluate.

Part III explores the possibilities and temptations for the abuse of DNA profiling. In light of the intimate details of an individual's private life that a DNA profile may reveal, this note urges an increase in the fourth amendment's protection against unreasonable searches and seizures in the context of individualized criminal prosecution. In the context of society at large, Part III considers the current effort to create a databank of DNA profiles of convicted felons and suggests that it threatens the security and privacy of us all. It further explains that immediate measures to limit the scope and use of such a databank are imperative for a free society.

Against the tide of unquestioning zeal for technological advances and war-like determination to sweep crime from the streets, this note urges restraint on the acceptance of unproven novel scientific techniques that turn courtrooms into laboratories and defendants into guinea pigs.

12. This note focuses on the use of DNA profiling evidence to inculpate criminal suspects. However, the evidence has also been instrumental in eliminating suspects. See Michael Connelly & Ashley Dunn, DNA Analysis in Crime Cases Waiting for Its Day in Court, L.A. Times, Aug. 21, 1988, § 2 (Valley Supp.), at 4, col. 1; Marshall Ingwerson, DNA Fingerprints: When the Proof Is in the Genes, Christian Sci. Monitor, Apr. 12, 1988, at 3, and should continue to be used in an exculpatory manner. Both from a scientific and a legal standpoint, the admissibility standard for the evidence can and ought to be lower when a defendant seeks to use the results of the test in his favor. See text accompanying notes 350-352 infra.
I. OUT OF THE RESEARCH LAB AND INTO THE FORENSIC LAB: SCIENTIFIC CONCERNS

A. Background

1. Goal of DNA profiling.

Forensics experts use DNA profiling evidence to aid in identifying the perpetrator of a crime. They seek to inculpate the criminal suspect by matching the pattern created by the suspect's genetic material with that created by genetic material obtained from a sample of human tissue the perpetrator left behind, or by matching blood found on a murder weapon or on the suspect's clothes with the victim's blood. The most common application of the technique in the criminal arena is in sexual assault cases, where the DNA profile of semen found in or on the victim's body is compared with a DNA profile obtained from a sample of the suspect's blood.

Although various other methods exist for comparing blood, hair, semen, and other fluids and tissues, DNA profiling has some distinct advantages. The DNA tests can be performed on much smaller tissue samples, these cases do not raise the same concerns of scientific reliability. See texts accompanying notes 55, 65 & 98-99 infra. Furthermore, civil defendants do not face the same penalties as convicted criminals and are therefore not entitled to receive the same constitutional protections as criminal defendants. Finally, there are policy reasons to admit the evidence in paternity and immigration cases that do not apply in criminal cases. For instance, in immigration disputes in the United Kingdom, DNA tests have been able to show that a much higher proportion of relationships are genuine (90%) than are accepted for entry into the country (50%). Mary Hibbs, Applicability of DNA Fingerprinting—Truth Will Out, 139 New L.J. 619 (1989); see also Alec J. Jeffreys, John F.Y. Brookfield & Robert Semeonoff, Positive Identification of an Immigration Test Case Using Human DNA Fingerprints, 317 Nature 818 (1985).

14. For instance, of 400 criminal cases that were handled by one of the commercial laboratories engaged in the testing, 75% were rapes. Moss, supra note 6, at 67.

As a preliminary caveat, the overall usefulness of DNA profiling evidence, even if it were reliable, has been vastly overstated in the criminal justice community. First of all, human tissue is not left at the scene of many crimes. Second, if it is left, it will often be too small or too degraded to type. Third, it only places the person at the scene, it does not establish guilt. Traditional defenses are always available. For instance, the evidence is potentially most valuable in rape cases, but semen is recovered in only a small number of those cases, and at least half of all rape defendants say that the intercourse was consensual. Stephen G. Michaud, DNA Detectives, N.Y. Times, Nov. 6, 1988, § 6, at 70, 104. Fifty percent of the rape cases referred to Lifecodes have not achieved results because the sample size was too small or the swab produced no semen. Moss, supra note 6, at 67.

15. E.g., ABO bloodtyping, HLA testing, and protein electrophoresis. For a description of these techniques and their limitations, such as lack of specificity and the requirement of large, fresh samples, see generally Paul C. Giannelli & Edward J. Imwinkelried, Scientific Evidence 575-601 (1986); Andre A. Moenssens, Fred E. Inbau & James E. Starrs, Scientific Evidence in Criminal Cases 324-414 (3d ed. 1986).
samples than traditional tests, which is important in forensics, where there is no control over the size of the samples left at the crime scene. DNA is also relatively hardy material. Therefore DNA typing is one of the few tests that claims a capability for typing old samples or those that have been exposed to varied environmental conditions.

More importantly, however, DNA typing is the first technique to point an accusatory finger at the suspect claiming, in effect, positive identification. Proponents derive this alleged certainty from the technique's basis in the scientific principle that each person's genetic makeup is unique. Too often, however, proponents of the technique confuse that basic principle with the abilities of the technique itself, greatly exaggerating its current potential.

2. General scientific principles.

Deoxyribonucleic Acid ("DNA") is a six-foot-long molecule found in the nucleus of every cell of the body. DNA carries coded information for the structure and operation of our bodies. Exactly the same

16. The DNA test generally requires ten hair roots, five milliliters of semen, or fifty milliliters of blood. Elizabeth Brown, Discovery Turns Researcher into Genetic Sleuth, AM. MED. NEWS, June 3, 1988, at 17. However, even that small requirement excludes a great many of the samples retrieved from the crime scene. In 50% of the rape cases referred to Lifecodes Corporation, the DNA typing test produced no results because the sample size was too small or the swab produced no semen. Moss, supra note 6, at 67. Lifecodes requires 100-200 microliters of blood for each test. An average drop of blood is about 25 microliters, so a sample retrieved from the crime scene is often not enough for testing. Isadora W. Lomhoff, By Their DNA, So Shall Ye Know Them, CAL. LAW., Feb. 1987, at 8, 9.

17. DNA has been isolated and typed from bloodstains as old as four years. Peter Gill, Alec J. Jeffreys & David S. Werrett, Forensic Application of DNA 'Fingerprints', 318 NATURE 577, 577 (1985); see also Barbara E. Dodd, DNA Fingerprinting in Matters of Family and Crime, 318 NATURE 506, 506 (1985). However, if the DNA is too old or poorly preserved, it will break up into tiny fragments having "low molecular weight" which cannot be reliably typed. William C. Thompson & Simon Ford, DNA Typing: Acceptance and Weight of the New Genetic Identification Tests, 75 VA. L. REV. 45, 65 (1989).

18. The most often quoted statistic is that the chance of a random match between two unrelated individuals is 1 in 30 billion. See Dodd, supra note 17, at 506; Gill, Jeffreys & Werrett, supra note 17, at 579. This statistic is very misleading and extremely disputed. See text accompanying notes 130-151 infra. By comparison, more traditional genetic marker blood-typing produces a 1 in 100 probability of a random match. Gill, Jeffreys & Werrett, supra note 17, at 578.

19. See text accompanying notes 130-153 infra.

20. Cells without nuclei, such as the mature red blood cells, do not contain DNA. DNA can also be found in the mitochondria, such as are found inside the hair shaft, but such DNA is of insufficient molecular weight for the purposes of most current DNA fingerprinting techniques. The DNA found in the hair roots, however, can be sufficient for testing. Marx, supra note 5, at 1617. This is useful since shed hair is the most common form of biological evidence found at the crime scene. Harold M. Schmeck, DNA: Identification From a Single Hair, N.Y. Times, Apr. 12, 1988, at C3, col. 1. For instance, in the first California case to admit the evidence in a criminal trial, the test matched the DNA in 15 hairs found at the scene of the crime with the DNA of the defendant. Denise Hamilton, Judge OKs Genetic Fingerprinting Use, L.A. Times, Aug. 8, 1989, at 3, col. 2. Trace amounts of DNA can also be found in noncellular bodily fluids such as saliva, urine, and sweat, which suffer from the same drawbacks as mitochondrial DNA but may eventually prove useful for testing as the technique improves. See Michaud, supra note 14, at 70, col. 3.
DNA composition is found in each cell of a particular individual. Thus, the same DNA can be found in the white blood cell, the skin cell, and the muscle cell of that individual. 21 Furthermore, an individual's DNA will typically stay the same throughout her life. 22 With the exception of identical twins, however, each individual's DNA is unique.

DNA is packed into twenty-three pairs of chromosomes. One half of each pair is inherited from the mother and the other half from the father. Each molecule of DNA is in the form of a double-helix, which looks like a twisting ladder. For the purposes of DNA profiling, the most important parts of the structure are the nucleotide bases, which pair up with each other and form the rungs of the ladder. The four bases are adenine (A), thymine (T), cytosine (C), and guanine (G). A always pairs with T, and C always pairs with G. The molecule can be thought of as a zipper with the bases as the teeth, and the two strands zipping or "hybridizing" according to their complementary bases in the following manner:

- G G A C C T A T C -
- C C T G G A A T A G -

A gene is a particular sequence of base pairs that codes for a particular structure, function, or feature, such as the gene for brown hair or the gene for green eyes. 23 There are approximately three billion base pairs in each DNA molecule supplying information. Because human beings are biologically more similar than different, i.e., we all have two legs, two eyes, etc., the sequence of most of the bases is the same from individual to individual. Yet about three million base pairs vary in sequence between any two individuals. 24 These areas of variation are

21. Although semen cells are very often used to make a DNA profile, it is worth noting a potential problem with semen samples. An individual receives half of his or her chromosomes from each parent—half from a sperm cell and half from an ovum. A sperm cell contains only half of a man's chromosomal complement, drawn at random from the whole. Studies have yet to determine if the DNA patterns resulting from semen samples may be misleading as to the entire makeup of an individual. Burk, supra note 3, at 469-70.

22. On rare occasions, mutations of the DNA may occur. Thompson & Ford, supra note 17, at 62. Additionally, chemotherapy may alter DNA. Burk, supra note 3, at 470 n.68. The fact that a minor mutation may occur is not insignificant. In the near future, law enforcement agencies will possess the capacity to scan a computer databank of DNA profiles in search of a match for an unknown sample of tissue found at the crime scene; this process is currently in place with the FBI's computerized fingerprint database. Possibilities of mutations increase the chance of erroneously declaring a match between the unknown sample and an individual whose DNA has mutated since the sample for the databank was taken.

23. Scientists have estimated that only about 45% of the bases in the DNA molecule are required for normal cell functioning, and the purpose of the other 55% is unknown. K.F. Kelly, J.J. Rankin & R.C. Wink, Method and Applications of DNA Fingerprinting: A Guide for the Non-Scientist, 1987 CRIM. L. REV. 105, 106. Scientists have identified the specific function of only 10% of the bases. This is not a small task. Researchers are mapping the entire human DNA sequence to identify the sections of DNA associated with disease. It has been estimated that a map could be completed by 6000 molecular biologists working full-time for 10 years. Laurel Beeler & William R. Wiebe, DNA Identification Tests and the Courts, 63 WASH. L. REV. 903, 907 n.11 (1988) (citing Bodmer, Human Genetics: The Molecular Challenge, 51 COLD SPRING HARBOR SYMPOSSIA ON QUANTITATIVE BIOLOGY: MOLECULAR BIOLOGY OF HOMO SAPIENS 1, 12 (1986)).

24. FBI DNA Fingerprinting: Hearing Before the Subcomm. on Civil and Constitutional Rights of
called "polymorphisms." A site is polymorphic when it has different alleles, i.e., alternate forms of a gene capable of occupying a single location on a chromosome. Different individuals may have different alleles from each other. For example, the gene for blood type has three alleles, A, B, and O, and an individual's blood type will depend upon which allele is occupying that polymorphic site on the chromosome.

Although each person's DNA is unique as a whole, no person has a unique DNA pattern at a given polymorphic site. Since it is impractical to compare all three million differing base pairs, the DNA profiling technique seeks to distinguish among individuals by focusing on several highly polymorphic or "hypervariable" sections of the DNA.

3. The mechanics of the technique.

Three commercial laboratories and the FBI currently perform the DNA profiling test to aid in identifying criminal suspects. Lifecodes Corporation, Cellmark Diagnostics, and the FBI each use "restriction fragment length polymorphism analysis" ("RFLP analysis"). Cetus Corporation uses "allele-specific probe analysis." Farther on the horizon is the refinement of a DNA base sequencing technique, which would be the most specific and detailed of the tests. Each of

the House Comm. on the Judiciary, 101st Cong., 1st Sess. 2 (1989) [hereinafter FBI DNA Fingerprinting Hearing] (statement of Dr. Eric Lander, Associate Professor at Harvard University and Fellow at Whitehead Institute for Biomedical Research) (on file with the Stanford Law Review) [hereinafter Lander Testimony].

25. The term "site" will be used interchangeably with "locus" and "area," all of which denote the segment of interest on the DNA.

26. See notes 43, 48 & 130 infra and accompanying texts.


28. Although the FBI's lab is the first publicly operated DNA typing lab, law enforcement agencies in several states are expected to open their own DNA typing labs soon. FBI Pushing DNA Identification for State and Local Agencies, CRIM. JUST. NEWS., Apr. 3, 1989, at 1, 1-2.

29. Lifecodes Corporation of Valhalla, New York is a subsidiary of Quantum Chemical Corporation. Lifecodes began forensic testing in 1987 and was the first U.S. firm to get DNA evidence into court and to obtain a conviction based on the evidence. Courts have admitted Lifecodes's DNA test results in 74 criminal cases in over 20 states. Michael Unger, Court Challenge Casts Pall over DNA Testing Industry, Newsday, July 30, 1989 (Business), at 47.

30. Cellmark Diagnostics of Germantown, Maryland is a subsidiary of ICI Americas, Inc., a corporation based in Great Britain. Cellmark's technique was developed by Dr. Alec Jeffreys, who is usually credited with discovering the forensic application of DNA analysis. See note 40 infra. Cellmark has the exclusive North American license to market Jeffreys's technique. The company opened in 1987 and obtained the first death penalty conviction in the United States based on the evidence.

31. The FBI opened its DNA laboratory for business in December 1988. See Andrew H. Malcolm, F.B.I. Opening Door to Wide Use of Genetic Tests in Solving Crimes, N.Y. Times, June 12, 1989, at A1, col. 1. Thus far, the FBI has conducted over 500 DNA tests and already has a backlog of 150 cases. Unger, supra note 29, at 47. The FBI began the testing in part because of law enforcement officials' desire to get DNA typing out of closed-door, profit-seeking private businesses and into a public arena. See Mark Thompson, DNA's Troubled Debut, CAL. LAW., June 1988, at 36, 44.

32. Cetus Corporation of Emeryville, California, has aided in 40 criminal investigations, but has not yet had its test admitted into court. Thompson & Ford, supra note 17, at 50.
these will be discussed briefly.\textsuperscript{33}

\textbf{RFLP analysis.}\textsuperscript{34} RFLP analysis has eight basic steps. The first step is \textit{DNA extraction}. DNA must be chemically extracted from the sample to be tested. The forensic sample is often dried blood or semen which must be washed from various surfaces such as clothing. Technicians then treat the sample with enzymes to release the DNA from the cells.

The next step is \textit{fragmentation by restriction enzymes}. A particular restriction enzyme will recognize a base sequence from four to eight bases long which appears throughout the DNA. The enzyme acts as a scissors and cuts the DNA only where that specific sequence occurs. A particular restriction enzyme will produce the same number and length fragments of DNA in a particular individual each time. If each individual’s DNA were the same, the enzymes would cut everyone’s DNA in the same place.

However, everyone’s DNA is not the same. RFLP analysis focuses on areas of the DNA that are highly polymorphic due to “length polymorphisms.” Length polymorphisms occur at a site on the DNA where a particular sequence of bases, sometimes referred to as a “mini-satellite,” is repeated a variable number of times.\textsuperscript{35} At that site, then, different individuals will tend to each have a different number of mini-satellites occurring between the restriction sites recognized and cut by the enzyme. This causes the length of the segments of DNA cut by the enzyme to vary among individuals.\textsuperscript{36}

The third step is \textit{gel electrophoresis}.\textsuperscript{37} Gel electrophoresis separates the DNA fragments by length. The DNA sample is placed in a hole at one end of the gel. An electric current is applied to the gel. Because DNA has a negative charge, the fragments will migrate toward the positively charged pole at the far end of the gel. The distance each fragment travels depends upon its size. The smaller the fragment, the

\begin{itemize}
\item \textsuperscript{33} Although all three techniques will be described, the remainder of this note will focus on the technique of RFLP analysis used by Lifecodes, since that is the one that has been most widely used and is under current debate. Allele-specific probe analysis and DNA base sequencing are not in the courtroom yet, but since they will be soon and raise several different concerns, they deserve some discussion.
\item \textsuperscript{34} For other thorough descriptions of the technique, from which the following discussion is partially drawn, see generally Burk, \textit{supra} note 3; John A. Tarantino, \textit{Convicted by a Hair, DNA Testing: A Primer on the Facts of Life}, 4 CRIM. JUST. 5 (1989); Thompson & Ford, \textit{supra} note 17.
\item \textsuperscript{35} Burk, \textit{supra} note 3, at 462-63; Jeffreys, Wilson & Thein, \textit{supra} note 27. The “mini-satellite” that is repeated a variable number of times in the polymorphic area of the DNA should not be confused with the sequence recognized by the restriction enzyme that appears throughout the DNA.
\item \textsuperscript{36} Scientists have identified more than 3,000 RFLPs, approximately 100 of which are highly polymorphic loci at which dozens of variant alleles are present in the population. Eric Lander, \textit{DNA Fingerprinting on Trial}, 339 NATURE 501, 501 (1989). Obviously, the higher the number of different alleles found to be present in the population, the better the locus for purposes of identification.
\item \textsuperscript{37} Gel electrophoresis is not the same process as “protein gel electrophoresis,” a method used for identifying genetic markers in the blood and semen that has received heated criticism in the past. \textit{See} note 273 \textit{infra} and accompanying text.
\end{itemize}
faster and farther it travels. Smaller fragments will thus cluster toward the far end of the gel and larger fragments toward the near end.

The next step is Southern blotting.\textsuperscript{38} Prior to this step, the DNA is "denatured," a chemical process which unzips the molecule so that it is single-stranded, separating each base from its complement. Southern blotting transfers the DNA fragments to a nylon membrane. This process occurs by capillary action: Buffer solution is pulled through the gel and the membrane and absorbed into paper towels, bringing DNA fragments with it. The DNA fragments bind to the membrane in the same positions as they were in the gel.

The fifth step is hybridization. For the purposes of distinguishing between individuals through a DNA profile, the only fragments of interest are those from the highly polymorphic area of the DNA. A radioactive DNA "probe" is used to locate and visualize those fragments on the membrane. The probe is a single-stranded section of DNA manufactured by genetic engineers\textsuperscript{39} that is designed to complement a single-stranded base sequence that appears in or adjacent to the highly polymorphic site. The probe seeks out and binds to the DNA fragments from that site. The probe is marked with a radioactive tag in order to locate the positions of those fragments.

Lifecodes, Cellmark, and the FBI use the same type of probe in criminal cases, known as a single-locus probe. Cellmark, however, also uses a multi-locus probe in civil cases.\textsuperscript{40} While the multi-locus probe seeks out DNA sequences that occur at several polymorphic loci in the DNA, the single-locus probe seeks out a specific sequence that occurs in only one polymorphic locus.\textsuperscript{41} The multi-locus probe thus results in a more specific, but more complex and more difficult to interpret, banding pattern, whereas single-locus probes produce simpler banding patterns that are easier to interpret.\textsuperscript{42} More than one single-locus probe—currently the private labs use three or four—must be used to get more specific results.\textsuperscript{43}

\textsuperscript{38} This technique is named after E.M. Southern who developed this method for visualizing DNA patterns at the University of Edinborough. \textit{See E.M. Southern, Detection of Specific Sequences Among DNA Fragments Separated by Gel Electrophoresis, 98 J. Molecular Biology 503 (1975).}

\textsuperscript{39} Probes are created using sophisticated recombinant DNA technology. Nonsynthetic probes are created by inserting a piece of human DNA in a microorganism where it is reproduced thousands of times. \textit{Burk, supra note 3, at 460.} Synthetic probes are created using a nucleic acid synthesizer which arranges the nucleotides in the desired order.

\textsuperscript{40} Cellmark's technique involving the multi-locus probe was developed by Alec John Jeffreys, Ph.D., at the University of Leicester in 1985. \textit{See generally Gill, Jeffreys & Werrett, supra note 17; Jeffreys, Brookfield & Semeonoff, supra note 15; Alec J. Jeffreys, Victoria Wilson & Swee Lay Thein, Individual-Specific 'Fingerprints' of Human DNA, 316 Nature 76, 78 (1985); Jeffreys, Wilson & Thein, supra note 27, at 72.}

\textsuperscript{41} Marx, supra note 5, at 1616-17; Thompson & Ford, supra note 17, at 72.

\textsuperscript{42} The single-locus probes produce two bands on the average, whereas the multi-locus probes produce about 15. Tarantino, \textit{supra note 34, at 7;} Thompson & Ford, \textit{supra note 17, at 72.}

\textsuperscript{43} For instance, Lifecodes found in its study of one RFLP that the probability that two
The next step is autoradiography. The blot is placed in contact with a piece of x-ray film, where the radioactivity of the probe exposes the film. Thus, bands will appear on the film where the probe has bound to the DNA. The pattern created has been repeatedly referred to as resembling a supermarket bar code; however, this is an extremely misleading analogy, since the bands are usually very fuzzy. This banding pattern is what has become known as the "DNA fingerprint." The position of the bands reflects the length of the DNA fragments produced by the cutting of the DNA by restriction enzymes at the polymorphic site.

The seventh step in the process is interpretation of the results. The pattern of bands produced by the suspect’s or victim’s DNA is compared to the pattern created by the unknown sample retrieved from the crime scene to see if there is a match. One method of declaring a match is simply by visual determination. However, given the complexity of the banding pattern in forensic DNA typing, the preferred method involves a computer to convert the band positions into numerical codes and compares the numerical codes to determine the closeness of the match.

The final step is the conversion into a statistical probability. Once the examiner declares a match, the next step is to assess the commonness of the particular DNA profile, i.e., the frequency of the alleles in the relevant population. The statistic is generated by consulting a database of results obtained by using the same probe on many individuals. The final statistic is usually expressed in terms of the odds of this match occurring at random in the relevant population. If more than one probe is used, the probability of a coincidental match becomes smaller. This is the most disputed step of the process and will be discussed in more detail below.

Allele-specific probe analysis. The results of allele-specific probe analysis are less specific than RFLP analysis, but the advantage of the technique is that it can work with smaller amounts of DNA than RFLP analysis. The probes used in this test are allele-specific, seeking out unrelated individuals in a given population will share an allele ranges from less than 1% to over 30%. M. Baird, I. Balazs, A. Giusti, L. Miyazaki, L. Nicholas, K. Wexler, E. Kanter, J. Glassberg, F. Allen, P. Rubinstein & L. Sussman, Allele Frequency Distribution of Two Highly Polymorphic DNA Sequences in Three Ethnic Groups and Its Application to the Determination of Paternity, 39 AM. J. HUM. GENETICS 489, 493 (1986). More than one RFLP must be analyzed for greater individualization. Moreover, the chances for misidentification are higher when only two bands produced by one probe match. Tarantino, supra note 34, at 41.

44. Rorie Sherman, Lawyers Attacking Test's Reliability, Nat'l LJ., July 3, 1989, at 14 (quoting forensic expert Randolph Jonakait); see text accompanying notes 75 & 78 infra.

45. See texts accompanying notes 130-153 infra.

46. This is the name William Thompson and Simon Ford give the test, see Thompson & Ford, supra note 17, at 76, but it is also sometimes called “PCR,” after the one step in the process that has made the technique most notable. See notes 49-50 infra and accompanying text.

47. The Cetus test claims to get results from one ten-thousandth the amount of DNA required by the other two companies. Thompson & Ford, supra note 17, at 50 n.29.
only one version of the polymorphic site. It is a binary test: it determines whether a certain allele is present or absent.

The step in this test that makes it most noteworthy is DNA amplification. After the DNA is extracted from a sample and purified, it is amplified by a “polymerase chain reaction” (“PCR”). This process increases the number of copies of the allele, making enough DNA to allow the test to be performed on what may have originally been a DNA sample of insufficient molecular weight. Due to this technique, Cetus claims to be able to conduct its test on a single hair. PCR is a technique that may eventually be used in the other tests to allow typing on smaller samples.

The other steps of the process employ similar techniques to RFLP analysis. The DNA is blotted onto a membrane and the radioactive probe is added. The blot is placed in contact with an x-ray film. If the allele is present, then the probe will expose the x-ray film, making a dot.

**DNA base sequencing.** Although this technique has not yet been employed for DNA forensic testing, it is used in research labs to discover the exact base sequence in the segment of DNA under study. Applied to forensic testing, the technique would locate the portion of the DNA that is highly polymorphic and compare samples by their base sequences, providing the most straightforward and specific method of comparison.

The legal community has yet to grapple with the implications of such a technique. The major difference between this technique and other DNA typing techniques is that base sequencing offers much more information about an individual than comparison of length differences or a simple binary test. This technology has the potential to come very close to the FBI’s dream of being able to reconstruct a descriptive physical profile of a suspect from a drop of blood or a fallen hair. Thus, the privacy concerns of individuals will be much more pronounced with this technology.

**B. Scientific Agreement on Principles**

Whether speaking for or against the application of DNA profiling techniques to forensics, scientists have yet to disagree with the general

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48. The results of the Cetus test are less specific because from 0.1 to 10% of the population may have the same type of allele at these sites. Tarantino, supra note 34, at 7.
49. PCR increases the number of copies of the allele in the sample to about 10 million. Id.
50. See Russell Higuchi, Cecilia H. von Beroldingen, George F. Sensabaugh & Henry A. Erlich, *DNA Typing from Single Hairs*, 332 Nature 543, 545 (1988). The testing of a single hair is presently only successful on hair that is pulled or has fallen, thus including the hair root, and not cut hair which contains mitochondrial DNA, which does not yet provide enough information for identification. Marx, supra note 5, at 1617.
52. See text accompanying notes 384-385, 394-418 infra.
principles of DNA profiling.53 Every high school biology student can recite the names Watson and Crick, who discovered the "double helix" structure of the DNA molecule in 1950, or Gregor Mendel, the Austrian monk whose famous pea plants helped him develop the laws of genetic inheritance in 1865. The principles of genetics these researchers and others developed have formed the basis of scientific experiments for many years; the experiments have repeatedly validated their underlying principles. Although it is possible that certain theories of genetics or properties of DNA will someday be hotly contested, at present these principles are accepted as truth.

For years, molecular and cell biologists have used many of the basic steps in the DNA testing process in research on genetic diseases.54 The procedures involved in RFLP analysis—DNA extraction, fragmentation by restriction enzymes, gel electrophoresis, Southern blotting, hybridization, and autoradiography—are generally considered reliable for diagnostic purposes.55

In diagnostics, the samples are undegraded, uncontaminated, and plentiful enough to allow for repeated testing. Unlike the forensic test, the diagnostic test does not seek to predict the likelihood of a random match between two samples, one of which is of unknown origin. As the next section will illustrate, the differences between the scientific techniques applied to diagnostics and those same techniques applied to forensics have thus far proven fatal to the reliability of the forensic test.

C. Lack of Scientific Consensus As to Practice: The Castro Case

Despite the intentions of some members of the legal community to withhold the introduction of the novel forensic technique until it is proven reliable enough to withstand judicial scrutiny, the promise of DNA identification evidence in criminal cases has proven too tempting

53. Dr. Eric Lander, a human geneticist at the Whitehead Institute for Biomedical Research at M.I.T., who has studied the technique at length, said, "The scientific community is in unanimous agreement that DNA Identification will be possible in theory. Various alternative procedures are currently being studied and evaluated—each based on a different technique—by a number of university research groups, by the FBI, and by a few private companies." Expert's Report of Dr. Eric S. Lander at 3, People v. Castro, No. 1508/87 (N.Y. Sup. Ct. 1989) (on file with the Stanford Law Review) [hereinafter Lander's Castro Report].

54. Human geneticists use RFLP analysis to trace the inheritance of chromosomal regions in families with histories of genetic disorders. In this research, they have located the genes causing diseases such as Huntington's disease and cystic fibrosis. Lander, supra note 36, at 501.

55. Thompson & Ford, supra note 17, at 65-74; see, e.g., J. Jay Gargus, Tools for the Molecular Analysis of Gene Structure and Function, in MOLECULAR BIOLOGY IN PHYSIOLOGY 19-34 (1989). However, note that certain techniques have never been questioned, in part because complete accuracy has not been crucial in diagnostics. For instance, scientists have always just accepted the reliability of Southern blotting. See Thompson & Ford, supra note 17, at 71. However, William Thompson and Simon Ford noted that bubbles on the membrane may block the transfer of DNA and cause certain bands to disappear. Id. at 91 n.200, 94 n.219. These technical issues may not have been as crucial in diagnostics, but they become important concerns when individual liberty is at stake.
for law enforcement officials to resist.\textsuperscript{56} The technique has gained popularity at an exponential rate from its introduction in the United States in 1987\textsuperscript{57} until now. It was initially hailed as "foolproof" and 99 percent positive; such exaggerations were based on the testimony of interested parties such as the scientists from those companies that sell their results at a profit and the prosecutors who use the results to gain convictions.\textsuperscript{58} Caught off guard by the storm, and perhaps assuming that there was no way around the damning evidence, defense attorneys were unable to combat the evidence effectively or find scientists to testify against it.\textsuperscript{59}

The first case to make inroads into the infallibility mystique of DNA profiling was \textit{People v. Castro},\textsuperscript{60} a double murder case in the Bronx. Twenty-year-old Vilma Ponce and her two-year-old daughter were stabbed to death in their apartment on February 5, 1987. There were few leads until police arrested the building's superintendent, Joseph Castro, and found some dried blood in the grooves of his watch, which

\textsuperscript{56} In September 1987, only one-third of the nation's crime lab directors thought DNA typing was ready for forensic use. Thompson, supra note 31, at 44. Professor George Sensabaugh of the University of California at Berkeley, a researcher in the field of forensic science and DNA typing, predicted in 1987 that it would take another five years of research before the DNA typing technique would be able to pass muster in California courts. Lombhoff, supra note 16, at 9.

\textsuperscript{57} In early 1988, consistent with such conservatism, California Attorney General John Van de Kamp held the firm position that DNA evidence was not ready for the courtroom. He explained, "We have every opportunity to botch this historic moment. How might we do that? By getting mesmerized with DNA's potential and slipping into a counterproductive scramble to rush the technology from laboratory to courtroom in record time." Thompson, supra note 31, at 40, 42.

\textsuperscript{58} However, only one year later, seeing that other jurisdictions were not hesitating to admit the evidence, Van de Kamp suddenly announced full-fledged endorsement of the procedure, preparing legislation to establish five regional DNA testing labs and to provide for a databank of DNA profiles of convicted sex criminals, thereby moving California from last to near first in the great race to admit this new crime-fighting technology. William Vogeler, \textit{Van de Kamp to Push for DNA Testing}, Daily J., Jan. 25, 1989, at 1, col. 2.

\textsuperscript{59} One marketing brochure proclaims, "To see justice served, ifs, buts, or maybes aren't enough. Get the definitive answer with Cellmark." Cellmark Brochure (on file with the \textit{Stanford Law Review}). Dr. Michael Baird of Lifecodes stated, "If you're a criminal, it's like leaving your name, address, and social security number at the scene of the crime. It's that precise." Ricki Lewis, \textit{DNA Fingerprints: Witness for the Prosecution}, DISCOVER, June 1988, at 44, 52.

\textsuperscript{57} See Thompson, supra note 31, at 41; notes 29-32 supra.

\textsuperscript{58} In September 1987, only one-third of the nation's crime lab directors thought DNA typing was ready for forensic use. Thompson, supra note 31, at 44. Professor George Sensabaugh of the University of California at Berkeley, a researcher in the field of forensic science and DNA typing, predicted in 1987 that it would take another five years of research before the DNA typing technique would be able to pass muster in California courts. Lombhoff, supra note 16, at 9.

\textsuperscript{59} Professor Barry Scheck, in his testimony before Congress in March 1989, said that in many of the pre-trial hearings on the admissibility of the DNA typing test, "there has been little, if any, informed cross examination of private DNA vendors and few qualified expert witnesses testifying in opposition. The defense lawyers in these cases, often court appointed counsel, have been overwhelmed." \textit{FBI DNA Fingerprinting Hearing}, supra note 24, at 5 (statement of Professor Barry Scheck, Cardozo School of Law) (on file with the \textit{Stanford Law Review}) [hereinafter Scheck Testimony].

\textsuperscript{60} No. 1508/87 (N.Y. Sup. Ct. 1989).
he said was his own. Prosecutors sent that specimen, samples of the victims' blood, and a sample of Castro's blood to Lifecodes for DNA typing. Lifecodes declared a match between the DNA in the blood on the watch and the DNA in Vilma Ponce's blood. If this case had followed the normal course of events in prior cases involving DNA evidence, Castro would have pleaded guilty right then, doubting his ability to fight the evidence in court.61

This case did not, however, follow the usual course of events. Defense attorneys Barry Scheck and Peter Neufeld sought and located experts who agreed to testify against the admission of the DNA typing evidence. For twelve weeks, New York Supreme Court Acting Justice Gerald Sheindlin listened to experts from both sides.62 The defense experts were able to uncover such serious blunders committed by Lifecodes in performing the test that the prosecution's main expert witnesses recanted their position. In an unprecedented move, two expert witnesses for the defense and two for the prosecution, after huddling outside of court, issued a statement declaring, "The DNA data in this case are not scientifically reliable enough to support the assertion that the samples ... do or do not match. If these data were submitted to a peer-reviewed journal in support of a conclusion, they would not be accepted. Further experimentation would be required."63 Ultimately, Justice Sheindlin ruled the evidence of the match inadmissible.64

This important case appears to have increased the dialogue among those members of the scientific community engaged in related diagnostic research and interested in a critical review of the technique as applied to forensics. Scientists in diagnostic research do not declare matches involving samples of unknown origin, and thus there are currently no generally accepted standards in the scientific community for such matching. Scientists in diagnostic research are not testing con-

61. See Ingwerson, supra note 12, at 3.

62. Defense expert witnesses were: Dr. Eric Lander of Harvard University and the Whitehead Institute for Biomedical Research at M.I.T.; Dr. Conrad Gillium of Columbia University and New York State Psychiatric Institute; Dr. Howard Cooke of the Medical Research Council in Edinburgh; Dr. Phillip Green of Washington University; and Dr. Lorraine Flaherty of the Kidney Disease Institute. Prosecution expert witnesses were: Dr. Richard Roberts of Cold Springs Harbor Laboratory; Dr. Michael Baird, Director of Forensic and Paternity Testing at Lifecodes; Dr. Pablo Rubinstein of the New York Blood Center; Dr. Carl Dobkin of Downstate Medical School and research scientist for New York State; and Alan Giusti of Lifecodes and physical scientist for the F.B.I. Decision on the Admissibility of DNA Identification Tests at 6, People v. Castro, No. 1508/87 (N.Y. Sup. Ct. 1989) (on file with the Stanford Law Review) [hereinafter Castro Admissibility Decision].

63. Lander, supra note 36, at 504. The four who met outside the courtroom were Dr. Eric Lander, Dr. Lorraine Flaherty, Dr. Richard Roberts, and Dr. Carl Dobkin. The other expert witnesses agreed with the conclusion. Schmeck, supra note 11, at B12, col. 5.

64. However, Sheindlin's decision was mixed. Although evidence declaring a match was inadmissible, evidence that the blood on the watch was not the defendant's was admissible. Castro Admissibility Decision, supra note 62, at 35. Furthermore, he ruled that the technique as a whole was generally accepted as scientifically reliable. Id. at 26-27.
taminated samples. Moreover, standards in the research laboratory do not need to be as strict as in the forensic laboratory:

Research scientists can tolerate relatively high rates of error and unreliability in their procedures. Scientific experiments which produce a finding of interest are usually repeated, sometimes many times, to be sure they are accurate. . . . In any case, errors tend to stand out because they are inconsistent with scientific knowledge and theory. The situation in a forensic laboratory is quite different. Tests often are not repeated. Errors 'stand out' and invite additional scrutiny only if they are inconsistent with the prosecution's theory of the case . . . [T]he acceptance of a procedure by research scientists may not be the best index of its acceptability for use in criminal identification.65

Perhaps the most important difference is that, in the forensic process, an individual's future is linked directly to the accuracy of the result.

Recent literature reveals critical flaws in the application of the diagnostic technique to forensics which render it unreliable from a scientific standpoint. The main criticism is not that it will never be reliable, but that the lack of uniform standards and quality controls allows the ambiguities and problems in the technique to go unnoticed, thus resulting in the scientifically unreliable declaration of a match.66

Specifically, before results of the DNA typing technique can be accepted as scientifically reliable in forensics, the following controls and standards must be developed: 1) controls to ensure the accurate interpretation of results; 2) standards for declaring matches; 3) standards for determining the probability of a coincidental match and for determining the relevant population studies; 5) standards for record keeping; and 6) standards for proficiency testing and licensing. This note will address each of these needs in turn.

1. **Lack of controls to ensure accurate interpretation of results.**

In the forensic laboratory, there are three problem areas which can lead to inaccurate results and thus errors in declaring matches between samples of DNA. One concerns the problems inherent in any scientific laboratory engaged in this type of research—namely, the problems of contamination and laboratory “slop.”67 Second, specific to the forensic lab are the likely problems of contamination and degradation in the

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65. Thompson & Ford, supra note 17, at 56-57.

66. "With due respect, the courts have been too hasty. Although DNA fingerprinting offers tremendous potential as a forensic tool, the rush to court has obscured two critical points: first, DNA fingerprinting is far more technically demanding than DNA diagnostics; and second, the scientific community has not yet agreed on standards that ensure the reliability of the evidence." Lander, supra note 36, at 501.

67. Laboratory "slop," a term used by William Thompson and Simon Ford, does not necessarily mean the lack of due care, but rather the inevitable variability and imperfection in testing conditions in a very complex procedure. See Thompson & Ford, supra note 17, at 87 n.188.
forensic sample. Finally, an inescapable problem for forensic DNA profiling specifically is the complexity of the results and potential examiner bias in interpreting those results. All three areas can cause the examiner to declare a false match and can remain undetected unless specific controls are employed.

**Problems inherent in the laboratory environment.** The laboratory environment and its procedures are not foolproof. A constant danger in any laboratory is cross-contamination between probe DNA and sample DNA or between two sample DNAs. If the probe contaminates the samples or the enzymes used on the samples, the probe will bind to itself in these samples, thus producing similar bands between the samples; this causes a false positive, thereby incriminating an innocent suspect. Alternatively, DNA from one of the samples could contaminate the other samples, thus causing each of them to produce similar bands.

The probe DNA or the sample DNA could also become contaminated with bacteria, which has DNA just like any other species. Thus, if a probe were contaminated, its use would produce misleading banding patterns. Not only would there be extra bands, but the bacterial bands could also obliterate human bands, which are much fainter. In Castro, Dr. Michael Baird, Director of Forensic and Paternity Testing at Lifecodes, testified that the company knowingly continued to use contaminated probes, "a procedure virtually inviting the occurrence of false positives and false negatives." Despite the fact that scientific controls to test for bacterial contamination in probes exist, Lifecodes did not employ such controls. Thus, when Lifecodes chose to discount two extra bands on the autoradiograph from the watch stain in order to declare a match between that sample and the sample of blood from Mrs. Ponce, it had done no tests to prove that the two extra bands were bacterial and not human. This example illustrates the seriousness of the need to implement uniform controls to test for contamination.

A second aspect of the laboratory environment which can lead to

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68. *Id.* at 96 n.226.
69. *Id.* at 94-95.
71. Lander, *supra* note 36, at 503; Lander’s Castro Report, *supra* note 53, at 23. Dr. Lander stated, “It is difficult to conceive of a more damaging statement about Lifecodes’ procedure. However, Dr. Baird managed to provide one: he testified . . . that it was not his practice to even bother to record in a laboratory notebook the fact that a probe was found to be contaminated.” Lander’s Castro Report, *supra*, at 23 (citation omitted).
72. Lander’s Castro Report, *supra* note 53, at 6. If there is bacterial contamination in only one of the lanes of sample in the gel, then there will be a chance of a false negative. If there is bacterial contamination in both of the lanes, then there will be a chance of a false positive. *Id.* at 23.
73. *Id.* at 13.
74. *Id.* at 14. A probe can be contaminated with other human DNA as well as bacterial DNA. For instance, the FBI told Dr. Lander that it discovered that a probe mixture it bought from Lifecodes produced an extra band determined to come from a different human RFLP probe used by Lifecodes but not by the FBI. *Id.*
erroneous interpretation is laboratory “slop,” due to the inevitable variability and imperfection of testing conditions and procedures in a very complex process. DNA patterns can be faint, blurry, or generally variable due to incomplete hybridization, variable mobility of DNA through the gel, variations in the thickness and consistency of the gels, or variations in the temperature and voltage level in the running of the gel.75

For example, incomplete hybridization can occur in “low stringency” conditions of the test. Temperature, salinity, and other conditions make up the “stringency” of the hybridization. In high stringency conditions, the probe will only lock onto fragments that are its complement, whereas in low stringency conditions, the probe will lock onto fragments that differ a certain amount,76 thus leading to inaccurate results. Stringency conditions required for each probe should be studied to determine the level which produces the most reliable results.

As another example, there are numerous possibilities for error in the Southern blot procedure. Bubbles on the nylon membrane may block the transfer of DNA and cause some of the bands to disappear.77 Often, poor quality Southern blots and faint and complex human DNA banding patterns combine to make interpretation of results extremely difficult.78 It may be difficult to identify a band from “background noise” common in human DNA profiles.79 For example, in Castro, the experts did not agree on how many bands they could see in several autoradiographs.80

Improved laboratory procedures would be the best solution, but, at the very least, controls are necessary to recognize the effects of laboratory slop and to ensure that they do not cause the examiner to falsely declare a match.

Contamination and degradation in the forensic sample. The second problem area is the contamination and degradation likely to be present in forensic samples. Contamination is the rule rather than the exception in forensic samples, a factor that simply is not tolerated in the normal laboratory environment.81 For instance, the forensic sample could have been removed from carpeting or clothing previously cleaned with detergents. The chemicals in detergents can cause the restriction enzymes to cut the DNA at the wrong place, causing fragments to be different lengths than they would normally be.82 Thus, contamination can

75. Thompson & Ford, supra note 17, at 87 n.188.
76. Id. at 74 n.133.
77. See note 55 supra.
79. Id. at 19-21.
80. Id.
81. Biochemist Richard Roberts of the Cold Spring Harbor Laboratory explained that samples in the lab are sterile; if a sample fell on the floor, he would throw it out and start over, “but in forensics, all of the samples have been on the floor, so you don’t really know what you’ve got.” Robert Cooke, Standards Sought for DNA Testing, Newsday, June 15, 1989, at 27.
82. Thompson & Ford, supra note 17, at 66, 68.
create a misleading result. contrary to the oft-stated claims of the test's proponents that only a smear would result from the presence of contamination.

In addition, the probability is high that the sample obtained from the crime scene is contaminated with bacteria. Thus, probes may bind to bacterial DNA and create a misleading result. The PCR technique employed by Cetus is particularly susceptible to contamination; it could amplify bacterial DNA rather than human DNA.

As indicated in the previous section, at the time of the DNA testing in Castro, Lifecodes had conducted no experiments to determine how much of the DNA recovered from a sample was human and how much was bacterial. The actual amount of purely human DNA may be too small for typing and, again, some of the bands appearing on the resulting DNA profile could be bacterial and not human.

The sample could also be contaminated with other human DNA because of the nature of the crime. For instance, if just prior to a rape, the victim was with her husband, or if the victim was raped by more than one person, the probe could bind to any of the DNA in the sample, producing a misleading result.

Not enough research has been done on contaminated samples at

83. Thompson and Ford note that partially digested DNA leading to a spurious alteration of the DNA print is more likely to exculpate a guilty suspect, since it would be unlikely for the alteration to cause two prints from different people to match. Id. at 93 n.214, 94; see also Mary-Claire King, Invited Editorial: Genetic Testing of Identity and Relationship, 44 Am. J. Hum. Genetics 179, 180 (1989). However, such a spurious alteration led to an erroneous match call by one of the labs during a blind proficiency test. See note 163 infra and accompanying text.

In any case, the legal community that is pushing the evidence through the courts appears unconcerned about the possibility of spurious alteration of the profile which would exculpate the guilty, a far more likely result of this test than a false match incriminating the innocent. If false incrimination does not give prosecutors pause, false exculpation should. However, until squarely faced with a case where all circumstantial evidence except the DNA profile points to a defendant's guilt, prosecutors will continue to opt for the odds that the test will be performed correctly.

84. See Stephen Strauss, DNA Fingerprinting, 91 Tech. Rev., Feb.-Mar. 1988, at 8, 8. In fact, studies performed thus far indicate that the DNA test has a chance of false positives comparable to the established biochemical tests for excluding suspects. Burk, supra note 3, at 467.

86. Tarantino, supra note 34, at 42.
87. See text accompanying note 73 supra. Lifecodes claims that the test performed in the Castro investigation was one of its first, and that it has since improved its technique, adding more controls and computer-aided analysis, Unger, supra note 29, at 47. For instance, Lifecodes now uses screening probes to detect nonhuman DNA. Beeler & Wiebe, supra note 23, at 922 n.95. However, the scientific community has not yet spoken on the effectiveness or reliability of such probes.
88. The smaller the amount of DNA in a sample, the fewer and fainter the bands, and the less reliable the results. See Beeler & Wiebe, supra note 23, at 919 n.76; text accompanying notes 91-93 infra.
89. See Burk, supra note 3, at 464; Tarantino, supra note 34, at 42. For instance, in an April 1989 gang rape of a jogger in New York's Central Park, the semen sample taken from the victim was probably a mixture of semen from several different individuals. An FBI report stated that the results of the DNA test were inconclusive. Ronald Sullivan, Genetic Lab Tests Are
this point to understand exactly how contamination affects the results. Since the experiment may be run only once in forensics, development of controls is crucial to ensure the reliability of the test.

Forensic samples can also contain degraded DNA. The longer fragments of DNA—those with high molecular weight—are the most likely to be degraded. The polymorphic probe will not bind to the degraded DNA fragments, and thus banding may not occur in the high molecular weight regions of the gel. Degraded DNA can thus produce a misleading banding pattern.

Small samples with low molecular weight DNA are particularly susceptible to such misleading results. For example, in the Hispanic population, 90% of the bands produced by a probe used by Lifecodes in Castro have high molecular weights. In Castro, the sample of blood from the watch, which Joseph Castro claimed was his own blood, was very small and badly degraded. Thus, there was a high probability that the test did not detect bands in the high molecular weight region of the gel.

Nevertheless, Lifecodes did not employ proper controls to ensure that an absence of bands in that region meant that none existed. The accepted control for degradation is the use of a nonpolymorphic probe. Nonpolymorphic probes bind to and produce patterns from an area of the DNA known to be shared by all humans. Thus, all human DNA should produce the same known banding pattern with such a probe. In Castro, Lifecodes should have used a nonpolymorphic probe on the watch sample that detects a band in the high molecular weight region of concern. If the nonpolymorphic probe detects the band, then the examiner can assume the polymorphic probe would have done so as well if a band had been present. If it does not detect the band, then the results are not reliable.

There are no standards on the use of nonpolymorphic probes in the laboratories performing the DNA typing test. Furthermore, there is little available research on the appropriate nonpolymorphic probes,

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Id. During the Castro case, when Dr. Baird was asked his level of confidence about the presence of undegraded DNA for the watch sample in the high molecular weight region of the gel, he stated, "I'd hate to bet the ranch on everything being there in a small size range." Id. at 16.

90. See Thompson & Ford, supra note 17, at 67.
92. Id.
93. Id.
94. Id. at 15-16.
95. Id. During the Castro case, when Dr. Baird was asked his level of confidence about the presence of undegraded DNA for the watch sample in the high molecular weight region of the gel, he stated, "I'd hate to bet the ranch on everything being there in a small size range." Id. at 16.
nor is there assurance that they are even available.97 Until such studies are conducted, the results in a forensic test are not reliable.

Problems of complexity in banding patterns. The third problem area for the accurate interpretation of the results of forensic DNA typing tests is purely the complexity of the resulting banding pattern. Interpretation of the results is not as problematic in diagnostic testing, where analysis involves identifying for a particular child which one of two possible bands was inherited from the mother and which one of two possible bands came from the father. Thus, for each person there are only four possibilities. This limitation acts as an internal consistency check in the diagnostic procedure.98 In forensics, on the other hand, a particular polymorphic site could have as many as one hundred alleles which produce DNA fragments of very similar lengths.99

Under these circumstances, molecular geneticists would not call a match without performing a "mixing experiment."100 To control for discrepancies between lanes due to laboratory slop101 as well as to ensure the accuracy of a match, smaller but equal quantities of the two samples being compared should be mixed and run in a lane beside the two lanes of separate samples. If all three lanes give identical patterns, then a match is more likely.102 If, however, there are extra bands or very wide bands in the mixed lane as compared to the separate lanes, then one cannot conclude there is a match.

In forensics, it may not be possible to run a mixed lane as well as running the samples separately if there is not enough DNA in the unknown sample. In Castro, Lifecodes could not do a mixing experiment because the watch sample was too small.103 Even if a mixing experiment is performed, the scientist is never sure if there are equal amounts of human, as opposed to bacterial, DNA. If, as is likely, there is more human DNA in the fresh blood than in the sample recovered from the crime scene, any extra unmatching bands in the recovered sample may be obliterated by the very wide bands produced by fresh, clean samples.

97. See id. at 52-53, 52 n.12 (citing testimony of defense experts Drs. Green, Lander, and Flaherty).
99. Castro Defense Brief, supra note 96, at 21, 25 (citing trial testimony). The technician must distinguish on average between 30 to 80 possibilities, without knowing those possibilities. Lander's Castro Report, supra note 53, at 4. For instance, at one commonly used polymorphic site, most of the alleles occupy only 2% of the entire length of the gel. Lander, supra note 36, at 501.
100. Lander's Castro Report, supra note 53, at 4; see also Castro Defense Brief, supra note 96, at 43 (Prosecution expert witness Dr. Roberts agreed that a mixing experiment is the correct way to declare matches with forensic samples.).
101. For instance, the two lanes can run at different speeds due to varying amounts of salt content or DNA in the lane, Castro Defense Brief, supra note 96, at 43, or the DNA can shift in its lane due to varying electrophoretic conditions, see Thompson & Ford, supra note 17, at 70.
103. Id. at 4.
potentially resulting in an erroneous declaration of a match.\(^\text{104}\)

Laboratories performing DNA testing are not required to perform a mixing experiment.\(^\text{105}\) If a standard did exist requiring labs to have a minimum amount of human DNA to do a mixing experiment, many of the small samples presently giving “results” would be considered insufficient to produce reliable results.

Even if a mixing experiment were conducted and the samples appeared to match, the examiner could not simply declare a match upon visual inspection. Due to faint banding patterns and the myriad possibilities of alleles of similar lengths for a given polymorphic locus, visual matching of DNA profiles is not acceptable in forensics.\(^\text{106}\) In Castro, Lifecodes scientists “eyeballed” the DNA profiles to discern if there was a match. All of the scientists testifying for the defense agreed that this was unacceptable\(^\text{107}\): Lifecodes’s own scientific papers call for the aid of a computer to declare matches.\(^\text{108}\)

Visual matching is also a subjective process particularly susceptible to examiner bias. The problem is exacerbated when the lanes of comparison are next to each other. In that case, the examiner who looks for a match is more likely to find one particularly because it would be consistent with the prosecutor’s theory of the case.\(^\text{109}\) Lifecodes’s Dr. Baird appeared to fall prey to such bias in Castro, as defense expert Dr. Eric Lander, human geneticist at the Whitehead Institute for Biomedical Research, could conceive of no other explanation for the fact that Dr. Baird ignored bands that would have ruled out a match and “saw”

\(^{104}\) Serial dilutions should be performed on the fresh sample so that its DNA has the same molecular weight as that of the unknown sample. Otherwise, when making lane-to-lane comparisons, the wide bands from the fresh sample may appear to match thin bands on the unknown sample, but there may not actually be a match since the center of the wide band is unknown. \textit{See Castro Defense Brief}, supra note 96, at 47 (citing testimony by prosecution expert Dr. Roberts). Lifecodes did not perform such dilutions in Castro. \textit{Id.} at 47-48.

\(^{105}\) \textit{See Castro Defense Brief}, supra note 96, at 52 n.12.

\(^{106}\) \textit{Lander’s Castro Report}, supra note 53, at 10. The Cellmark multi-locus probe technique is particularly prone to such results because the probe it uses produces numerous bands and may produce unreadable results where the longer DNA fragments have degraded. \textit{Beeler \\& Wiebe}, supra note 23, at 924 \\& nn.110-111.

\(^{107}\) \textit{Castro Defense Brief}, supra note 96, at 24-26. Howard Cooke of the Medical Research Council in Edinburgh, who developed two of Lifecodes’s probes, doubts that visual matching could be done with any certainty. \textit{Barinaga}, supra note 7, at 89.


\(^{109}\) “[L]ane-to-lane comparison to distinguish between bands . . . is inappropriate in DNA fingerprinting analysis of unknown samples—as one runs the risk of discounting precisely those differences that would exonerate an innocent defendant.” \textit{Lander}, supra note 36, at 502.
bands where there were none in order to create a match:\(^{110}\):

In scoring autoradiograms, there is a strong tendency to compare across lanes, giving more weight to a potential band if it is “confirmed” by the presence of a corresponding band in another lane. Because of this substantial subjective bias to see bands where one expects to see bands, careful controls are an essential part of molecular biological experiments.\(^{111}\)

To control for such examiner bias as well as for errors in visual matching, lane-to-lane comparisons should be disallowed,\(^{112}\) and computerized scoring of the band positions should be mandatory. Furthermore, the examiners should be told neither the origin of the samples\(^{113}\) nor the prosecution’s theory of the case. Finally, any declaration of a match should be confirmed independently by at least two examiners.\(^{114}\)

Reproducibility is the fundamental test for acceptance of results in the scientific community.\(^{115}\) In Castro, the faulty interpretations of the autoradiographs were not reproducible.\(^{116}\) Many of the problems experienced in Castro can be rectified by the implementation of proper controls to catch errors and ensure accurate interpretation. Until the proper controls are researched and implemented, the results obtained in DNA typing tests are not reliable.

2. Lack of standards for declaring matches.

Even if interpretation of the banding pattern is eventually considered reliable, this does not solve the basic problem of the lack of objective criteria in the scientific community for declaring a match.\(^{117}\) For instance, Lifecodes’s stated rule was to declare a match between two bands when they were within three standard deviations of each other.\(^{118}\) This is a much more liberal matching standard than used in most scientific studies which declare two standard deviations to be statistically significant.\(^{119}\) Furthermore, Lifecodes did not even adhere to this standard in Castro, when it used a new “averaging method” that was not scientifically sound and allowed it to declare a match outside three

\(^{110}\) Lander’s Castro Report, supra note 53, at 11-12, 12 n.13, 14 n.19.

\(^{111}\) Id. at 12 n.13.

\(^{112}\) Defense expert Dr. Gillium testified that in his lab, the lanes are loaded randomly rather than side by side to prevent comparisons across lanes which might invite examiner bias. Castro Defense Brief, supra note 96, at 57.

\(^{113}\) This is a suggestion by Dr. Lander. Lander’s Castro Report, supra note 53, at 21 n.25.

\(^{114}\) Defense experts Lander, Gillium, and Flaherty all addressed the need for blind reading of autoradiographs by at least two truly independent examiners. Castro Defense Brief, supra note 96, at 56. At Lifecodes, instead, the first examiner told the second her results before the second examiner reviewed it, and if the two disagreed, rather than repeating the test, the first deferred to the second’s opinion. Id. at 57.

\(^{115}\) Lander’s Castro Report, supra note 53, at 21.

\(^{116}\) Id. at 22.

\(^{117}\) See Lander, supra note 36, at 501; Thompson & Ford, supra note 17, at 88.

\(^{118}\) See Lander’s Castro Report, supra note 53, at 9.

\(^{119}\) See id. at 10.
standard deviations.120

Acceptable matching criteria for forensic purposes may elude scientists as long as patterns continue to be faint, blurry, and generally variable, and contamination and degradation of the samples cause the patterns to change. Furthermore, there is the possibility that two very different fragments on two separate samples or within the same sample will have the same length, a fact which substantially undermines the technique’s reliability.121 This is one of the dangers of the whole scheme of distinguishing among individuals only by length of DNA fragments. Studies must be conducted to determine whether it is possible to construct an acceptable range of variation within which to declare a match.

Yet, a determination of a standard for declaring matches can never be truly objective. The question of where to set the threshold determination for declaring a match is ultimately a policy question. The dilemma that is raised can be illustrated as follows: If a sample matches another sample in ten out of twelve bands, it is probably more likely that the two extra bands were produced by slop than that two random individuals would share those ten bands in common. If the examiner adopts a high threshold for matches, she may exculpate a suspect whose DNA profile is a match. If the threshold is too low, she may declare a match between two different individuals and inculpate the innocent.122

Thus, even if the scientific community defines matching standards, the standards will necessarily be political in nature. If the FBI is allowed to promulgate these standards, as is expected,123 then it is likely that the state’s need to fight crime will take precedence over any desire to protect individual rights.124 A low threshold for declaring a match threatens the presumption of innocence we give to a criminal defendant and undermines a justice system predicated on the notion that it is better to let the guilty go free than to condemn one innocent person.

3. Lack of standards for choice and number of polymorphic sites studied.

There have been no independent validation studies on the probes used by the various laboratories engaged in DNA typing to ensure that

120. See id.
121. Burk, supra note 3, at 465.
122. Thompson & Ford, supra note 17, at 88-91.
123. After a hearing on DNA profiling before the House Judiciary Subcommittee on Civil and Constitutional Rights in March 1989, the chairman of the panel wrote to FBI Director William Sessions, “The witnesses and the Subcommittee were encouraged that the FBI is now taking a leadership role with this potentially very useful new technology.” Letter from Rep. Don Edwards to William Sessions (May 8, 1989) (on file with the Stanford Law Review) [hereinafter Letter from Edwards to Sessions]. Edwards said “the law enforcement community nationwide is looking to the FBI for guidance.” CRIM. JUST. NEWSL., Apr. 3, 1989, at 4.
124. See text accompanying notes 420-421 infra.
they identify highly polymorphic areas in all individuals.¹²⁵ Nor is there a consensus on which of the highly polymorphic probes are most reliable. For instance, choosing one that locates bands in the high molecular weight region of the gel, as Lifecodes did in Castro, “courts disaster,”¹²⁶ and choosing probes that detect more than two bands, as Lifecodes did in Castro, makes misinterpretation of the banding pattern more likely.¹²⁷

Furthermore, there are no standards as to the number of probes required to ensure the greatest specificity in identification of an individual. Although molecular biologists have described more than 2000 sites of genetic variation, the tests used in criminal prosecutions have probed as few as three sites for a given sample.¹²⁸ The lower the number of variable sites tested, the less specific and reliable are the results. Dr. Lander recommended that forensic scientists increase the number of different probes used from three or four to between eight and ten: This would decrease the chance of a false match by a factor of at least 1,000,000.¹²⁹

4. Lack of standards for determining probability of a coincidental match and lack of relevant population studies.

The fact that no individual has a unique DNA profile at a given locus cannot be overstated.¹³⁰ Only an individual’s DNA taken as a whole is unique. Thus, the importance of DNA profiling lies in its ability to compare as many loci as possible between two samples, and if they appear to match, to calculate the probability that this match could be a coincidence. There are no standards in the scientific community for such calculations, since diagnostic research does not require this step. The methods used to determine the probability statistic are likely to remain hotly contested, since once the declaration of a match is in evidence, it is the statistical probability of a random match which the jury must consider to determine if the sample found at the scene is indeed the defendant’s.

The probability determinations involved in this calculation are all very problematic as currently made. The most important criticism has been the choice of the relevant population when determining the probability of a coincidental match. For instance, the oft-quoted statistic that the chance that two individuals would have the same DNA profile is one in thirty billion is based on a study of fourteen British

¹²⁵. Thompson & Ford, supra note 17, at 73-74.
¹²⁷. Id. at 10-11. The FBI has adopted a rule against using probes that typically detect more than two bands. Id.
¹²⁸. Id. at 3.
¹²⁹. Lander Testimony, supra note 24, at 4.
¹³⁰. See Castro Defense Brief, supra note 96, at 18; notes 43 & 48 supra.
Caucasians. Based on such a small, homogeneous population, which could have a very different distribution of alleles than the population at large, the data generated simply cannot be translated into a reliable overall statistic for anyone in the population.

The sufficiency of the size of the database used for population studies has been the source of much debate. There is no scientific consensus on the proper database size from which it is acceptable to project statistics for an entire population. For instance, the studies published by Lifecodes on allele frequency in a population have been based on small groups of about 200 to 300 people, mostly from New York. Until a much wider database is built, statistical estimates about frequencies of alleles in the entire population should be conservative.

For scientists properly to calculate the probability statistic, the population studied must be freely mixing, such that there is an equal distribution of alleles within the population. Since a particular racial group will have more alleles or combinations of alleles in common than the population at large, Lifecodes and Cellmark separate their samples by race. For instance, they calculate the frequency of a particular allele in the Hispanic population to reflect the fact that the chance of a coincidental match is much higher in this population than in the population at large. In separating samples only by race, the laboratories are assuming that within each race the population is freely mixing and therefore homogeneous in the distribution of alleles among its members. A freely mixing population is said to be in "Hardy-Weinberg equilibrium."

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131. Jeffreys, Wilson & Thein, supra note 27, at 68.
133. In Cobey v. State, No. 1515-1988, (Md. Ct. Spec. App. 1989), where the court decided that the Cellmark DNA test results were reliable, the defendant unsuccessfully claimed that Cellmark's database of 700 individuals was insufficient, but had no expert witnesses to refute the four prosecution expert witnesses who claimed that the database fell within generally accepted scientific criteria. Maryland Court Approves Admission of DNA 'Fingerprint' Test Results, 45 CRIM. L., July 26, 1989, at 2289.

The Florida District Court of Appeal similarly rejected appellant's arguments in Andrews v. State, 533 So. 2d 841, 850 (Fla. Dist. Ct. App. 1988), that Lifecodes's database of 710 samples was too small to be statistically significant, citing testimony that as the database expands, the probability numbers do not drastically change. There were also no defense experts in this case to refute such testimony.

134. In Andrews, Dr. Baird testified that no one worries too much about the size of the database and appeared to base this statement on the fact that there was so little published on the subject. Record, Vol. III, at 510, State v. Andrews, No. CR87-1400 (Orange County Cir. Ct., Fla. 1988) (on file with the Stanford Law Review) [hereinafter Andrews Record] (direct testimony of Dr. Michael Baird, Director of Forensics and Paternity Testing at Lifecodes) [hereinafter Direct of Baird]. The only set of guidelines of which he knew was a 1982 American Association of Blood Banks publication stating that database sizes from two to five hundred should be adequate. Id. However, this was before the development of forensic DNA typing, which studies many different rare alleles in the population, unlike paternity testing or protein gel electrophoresis.

135. See Thompson & Ford, supra note 17, at 84 n.177.
rium,” and one uses the “Hardy-Weinberg equation” to determine the frequency of the alleles in such a population.

The laboratories’ assumption of Hardy-Weinberg equilibrium for race populations is not well-founded, however. Since a population defined only by race is large and amorphous, the population is probably not freely mixing and homogeneous, but is heterogeneous, with various subpopulations. For example, it is quite possible that within the Hispanic population, Puerto Ricans, Cubans and other subpopulations tend to marry members of their own ethnic community. If that is true, then the Hispanic population is not freely mixing. In addition, particular neighborhoods may be heavily inbred due to their lack of mobility, increasing dramatically the likelihood that the group has many more alleles in common than the population at large. If such subpopulations exist and the general population is therefore not freely mixing, the Hardy-Weinberg equation cannot be used to describe the Hispanic population, leaving one without an accepted method for calculating allele frequencies in the population or the subpopulation. The probability of a coincidental match based on the entire Hispanic population grossly underestimates the actual probability within a subpopulation.

In Castro, defense experts Drs. Lander and Green used Lifecodes’s raw data to calculate whether the Hispanic population was in Hardy-Weinberg equilibrium and concluded that it was not. Dr. Green stated that the only explanation for the discrepancy was that Lifecodes must have purposefully redefined its data to place it in equilibrium. Furthermore, Lifecodes had written and published an article based on this data, and Dr. Green, who had been the peer reviewer who accepted the article, testified that if he had known that the data was

137. Lander, supra note 36, at 501.
138. The probability that two individuals will share the same alleles increases immensely when the two individuals are related. For instance, for one probe studied by Dr. Jeffreys, the probability of a coincidental match increased by a factor of 1,000,000 when the two individuals were related. Jeffreys, Wilson & Thein, supra note 27, at 77.
139. Lander, supra note 36, at 504.
140. Dr. Lander gives an example:

“[A] rape-murder was committed in Furney-Richardson, Texas—a tiny town with a population of about 100 residents, almost all black and closely related. DNA samples from six suspects were compared with semen samples, and a match was declared with one suspect. The jury was told that the chances of a match occurring at random was 1 in 96,000,000. This was based on surveys for the whole American Black population—ignoring the fact that the residents were closely related and were observed to share an unexpectedly high proportion of DNA variants in common. Moreover, the jury was not told that a relative of the accused had fled town—even though this individual had a much larger chance of matching the DNA sample than 1 in 96,000,000. The accused has been sentenced to death.”

Lander Testimony, supra note 24, at 5.
142. Id. at 38.
143. See Balasz, Baird, Clyne & Meade, supra note 108.
The probability of subgroup variation from the population has not been properly considered or studied.\textsuperscript{145} Since the DNA typing test searches for rare alleles and such alleles are often not found in Hardy-Weinberg equilibrium,\textsuperscript{146} a method for calculating the frequencies of such alleles must be developed.\textsuperscript{147}

Not only must a population be in Hardy-Weinberg equilibrium to calculate allele frequency, it must also be in "linkage equilibrium." Linkage equilibrium assumes that the alleles found by the use of one probe on a sample are independent from the alleles found by any of the other probes used on the same sample. Assuming this is true, Lifecodes and Cellmark use the product rule to multiply together the results from each probe to get an overall frequency of those alleles occurring together in the population. Linkage disequilibrium occurs when the polymorphic areas studied by two different probes are in close proximity and therefore the alleles may not be inherited independently. This can usually be avoided by probing areas on different chromosomes. It cannot be avoided, however, once it is determined that a population is heterogeneous and thus not in Hardy-Weinberg equilibrium. In other words, if an individual possesses an allele common among Puerto Ricans at one locus, it is more likely that she will possess the same allele as another member of the Puerto Rican population at a second locus as well.\textsuperscript{148} There is no generally accepted method for determining allele frequencies when a population is not in linkage equilibrium.\textsuperscript{149} The use of the product rule for a subpopulation grossly underestimates the probability of a chance match.

In determining the frequency of the allele in a population, assuming it is in Hardy-Weinberg equilibrium, the same standard used to declare a match between two samples must be used to determine the frequency of that same match in the population. If not, a misleading statistic results.

For example, in Castro, Lifecodes declared a match between two samples using its rule of declaring matches between bands that lie within three standard deviations of each other. Thus, when referring to its database to determine the probability that this match could occur at

\textsuperscript{144} Castro Defense Brief, supra note 96, at 37-38.
\textsuperscript{145} The FBI is currently attempting to define homogeneous subpopulations within the Hispanic population. Lander's Castro Report, supra note 53, at 31. However, a recent study of the fairly homogeneous Utah Mormon population showed deviation from Hardy-Weinberg equilibrium, suggesting that finding homogeneous subpopulations may be difficult. Id. Thus, there may be very few groups for which the Hardy-Weinberg equation may be used.
\textsuperscript{146} For instance, the mutation that causes Tay-Sachs disease is much more common among Ashkenazi Jews than among the general Caucasian population. Id. at 32.
\textsuperscript{147} Id. Almost no raw data has been published from which to calculate the frequency of a given allele in the general population or a subpopulation. Burk, supra note 3, at 466, 466 n.42.
\textsuperscript{148} Lander, supra note 36, at 504; Castro Defense Brief, supra note 96, at 40.
\textsuperscript{149} Lander's Castro Report, supra note 53, at 33.
random, Lifecodes should add together all of the samples in the database which had bands occurring within three standard deviations of the matching band on the sample. Instead, Lifecodes only counted as "matches" bands occurring within two-thirds of a standard deviation, a procedure that deviated from Lifecodes's published standards as well as scientific norms.150

By using a stricter standard to determine the probability of a match in the population than that used to determine a match between two samples, Lifecodes grossly underrepresented the probability of a random match in the population. In fact, Lifecodes stated the probability of a random match in Castro as one in 100,000,000, and defense expert Dr. Lander recalculated the statistic using Lifecodes's published procedure and obtained a one in 78 chance of a random match.151 Dr. Lander also calculated the probability using the approach adopted by the FBI and obtained a one in 24 chance of a random match.152 He concluded, "That Lifecodes's claims and the FBI's methods produce such radically different results . . . speaks volumes about the absence of a generally accepted procedure for performing DNA Identification."153

5. Lack of recordkeeping standards.

The lack of recordkeeping standards is far from trivial. Validation and reproduction of the results by referring to accurate and complete records is crucial to the reliability of the technique. For instance, Lifecodes did not record which of its probes were contaminated, and it continued to use and sell such probes, which could produce false positives in a DNA typing test.154

In Castro, Lifecodes had incomplete and contradictory lab records; "it relie[d] on whatever its technicians happen[ed] to record on a given day in their laboratory notebooks."155 Such records proved disastrous for Lifecodes in Castro and invalidated an entire procedure. Lifecodes technicians did not record whose blood was the control for the test used in Castro to determine the sex of the source of the bloodstain on the watch. The control lane did not produce a band for the Y chromosome indicating that the source of the control sample was female. At first, Dr. Baird testified that the source was female. However, when confronted with conflicting testimony that the source of the blood was male, Dr. Baird reversed himself and stated that the reason there was no band for the Y chromosome was because the particular male scientist had a rare short Y chromosome.156 However, this was highly un-
likely, so Dr. Baird then suggested that the source was a different woman.157 Lifecodes did not run any tests to prove any of these presumptions.158 Under such circumstances, incomplete records force the conclusion that the test was not reproducible and hence was unreliable.159

Thus, record keeping is clearly an important part of the integrity of the procedure. Standards for record keeping are even more crucial if the results are admitted into court, since the records are one of the few ways for the opposing party to review the accuracy of the test.

6. Lack of proficiency testing and licensing standards.

"Forensic science, including DNA testing, is operating in a no- man's land where there are no accredited standards for the laborato- ries," according to forensic evidence expert Randolph Jonakait.160 Dr. Eric Lander echoes this sentiment: "At present, forensic science is vir- tually unregulated—with the paradoxical result that clinical laborato- ries must meet higher standards to be allowed to diagnose strep throat than forensic labs must meet to put a defendant on death row."161

Critics have lamented the lack of proficiency in forensic labs in the past. In a three-year study funded by the Justice Department, forensic laboratories received identical dried blood stains; 71.2 percent of the 128 labs participating in the study either mistyped the sample or reported inconclusive results.162 This lack of proficiency in state laborato- ries is frightening, as most DNA typing will ultimately be performed by these same laboratories.

In 1987, the California Association of Crime Laboratories con- ducted the only proficiency testing to date of the three private laborato- ries engaged in DNA typing. Fifty samples were sent to each lab. Cetus and Cellmark mistakenly matched unrelated samples.163 They did not complete fifty tests without inculpating an innocent person—surely an unproficient result. Although Lifecodes called all fifty correctly, its re- searchers, rather than the technicians who usually perform it, com- pleted the test.164 This type of testing is not nearly as rigorous as blind testing programs, where blind tests are interspersed among real cases.165 The test only required stating whether there was a match, and

157. Id.
159. Id. at 17.
161. Lander, supra note 36, at 505.
163. They identified the problems as the non-binding of DNA to a filter and the acciden- tal mixing of two samples.
164. See Barinaga, supra note 7, at 89; Lander Testimony, supra note 24, at 3-4.
165. See Lander Testimony, supra note 24, at 3-4.
not how close the match was or where the bands were located, and so the laboratories had a fifty-fifty chance of getting it right.

The technique as currently practiced, without guidelines or standards, is complex and sophisticated, and it is doubtful that forensic crime labs will be able to perform the DNA typing test.\(^\text{166}\) Passing a battery of blind tests should be required before a crime laboratory is allowed a license to make determinations that affect an individual’s freedom.

D. Proposal for Uniform Validation and Standards

Castro, as well as the March 1989 hearings before the House Judiciary Committee’s Subcommittee on Civil and Constitutional Rights,\(^\text{167}\) convinced many interested parties that uniform standards are vital to ensure the reliability of DNA profiling in criminal cases. As a result of the hearings, the Subcommittee strongly recommended that the FBI take the lead in developing the following: 1) an independent system of proficiency testing and licensing; 2) guidelines and protocols in testing to serve as national advisory standards for forensic DNA profiling; 3) requirements that labs keep records and disclose scientific ambiguities in results; 4) uniform standards for declaring matches; and 5) continued research on population frequency data.\(^\text{168}\) In addition, the Subcommittee suggested that legislation may be necessary.\(^\text{169}\)

Congress has asked its Office of Technology Assessment (“OTA”) to prepare a report on DNA typing by the end of 1989. As part of that project, OTA has commissioned Dr. Lander to write a report on the underlying technical issues in DNA profiling.\(^\text{170}\) The report could provide information to help Congress design regulatory legislation.\(^\text{171}\) The National Academy of Sciences has also formed a committee to prepare guidelines for courtroom use of DNA profiling evidence.\(^\text{172}\) Finally, the National Institute on Standards and Technology is conducting a study on the competing methods of DNA typing to determine which are the most reliable.\(^\text{173}\)

Although all of these efforts are commendable, coordination is sorely lacking. Prosecutors continue to employ DNA testing while

\(^{166}\) Critics contend that it is not reasonable to expect that clinical or crime labs will be able to perform a technique as specialized as Southern blotting of single-locus probes. King, supra note 83, at 180.

\(^{167}\) Among those testifying were: Law Professor Barry Scheck, defense attorney for Joseph Castro; Dr. Eric Lander of the Whitehead Institute of Biomedical Research; John Hicks, Deputy Assistant Director, FBI; and Engineering and Public Policy Professor Philip Bereano.

\(^{168}\) Letter from Edwards to Sessions, supra note 123.

\(^{169}\) Id.

\(^{170}\) Lander’s Castro Report, supra note 53, at 37.

\(^{171}\) Barinaga, supra note 7, at 89.


\(^{173}\) Lander’s Castro Report, supra note 53, at 37.
these groups are still deciding among various courses of action. If defendants find themselves on death row because of DNA evidence that is later found to be unreliable, due process is completely subverted.

This note proposes implementing a working committee of scientists whenever forensic crime laboratories intend to employ a new technique for the first time. The National Academy of Sciences would chair this committee, which would be comprised of disinterested experts in the relevant fields of science as well as members of the FBI and state laboratories. The threshold question would be a scientific one, not a legal one: What must be done to ensure the reliability of this technique?

This representative committee would subject the technique to rigorous peer-review and independent validation studies. It would publish the results of such studies, and, assuming it decides the technique can be implemented reliably, it would issue uniform rules of laboratory protocol. Moreover, before any laboratory could use the new technique, this committee would administer a series of blind proficiency tests and require the laboratories to meet a designated standard.

It should be a national imperative to have the scientific community pass on the accuracy and reliability of a test before the legal community incorporates it into its crime prevention scheme.

II. OUT OF THE FORENSIC LAB AND INTO THE COURTROOM: LEGAL CONCERNS

The revelations by experts in Castro of DNA profiling’s unreliability should serve to curb the zeal of prosecutors and judges who are pitting cutting-edge technology against the criminal defendant. The uncertainties of the technique should cause the legal community to pause and reevaluate the technique’s reliability in the forensic arena. These uncertainties should provoke a probing examination of the admissibility standards for novel scientific evidence in the courtroom to understand why DNA profiling evidence was so quickly embraced as reliable in cases that preceded Castro.

However, more recent cases are already attempting to portray Castro as a blip on the forensics screen, a mere “speed bump” on this technology’s fast track to admissibility. Even if the more glaring mistakes

174. This was also suggested by Dr. Lander. Lander, supra note 36, at 505. Such a committee has historic precedent. In the late 1970s, the FBI requested that the National Academy of Sciences (NAS) evaluate the reliability of voiceprint evidence. The NAS concluded that the forensic application should be applied with more caution than it had been in the past. Although the courts professed to adopt the study as their standard, some courts continue to ignore it. Beeler & Wiebe, supra note 23, at 953 n.260.


made by Lifecodes in Castro were not made in these cases, or if particular test results in subsequent cases were accurate, Castro uncovered a myriad of problems that demonstrate the unreliability of the technique as a whole. More importantly, as this note will demonstrate, Castro teaches that the courts are not the proper forum for assessing the reliability of a forensic technique as sophisticated as DNA profiling.

Courts currently employ one of two tests to assess the admissibility of novel scientific evidence. The majority of jurisdictions follow the older, more stringent test promulgated in Frye v. United States, described below. However, as the amount of scientific evidence in the courtroom proliferates, a growing number of jurisdictions have abandoned the view that scientific evidence is distinct from other forms of evidence and have opted for a simpler relevancy standard. Thus far, despite the decisions of many courts to the contrary, DNA profiling, as currently employed in forensics, does not pass either test.

A. DNA Profiling Fails the Frye Test


In Frye, the court excluded a form of lie detection evidence that was a precursor to the modern polygraph, stating:

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


177. For a discussion of other cases where many of the same serious scientific problems exist, see Lander, supra note 36, at 505.

Both individual validity and overall reliability are necessary for the results of a test to be admissible in any given case. One commentator explained that the “validity” of the technique refers to the accuracy of the result in an individual test, whereas the “reliability” of the technique means the consistency of the results taken together. Paul C. Giannelli, The Admissibility of Novel Scientific Evidence: Frye v. United States, a Half-Century Later, 80 COLUM. L. REV. 1197, 1201 n.20 (1980).

178. Not all scientific evidence qualifies for this special category of "novel scientific evidence" requiring a heightened level of judicial scrutiny. If it is not necessary to apply a scientific principle to a particular line of proof to make it meaningful to the factfinder, the judicial inquiry need only focus on the process by which the data was obtained. However, the judge may still be able to establish the admissibility of scientific evidence through judicial notice if the scientific principle or technique is considered to be a generally known fact. The principles underlying blood tests and fingerprinting, as well as the validity of the techniques themselves, are now universally accepted and recognized through judicial notice. John William Strong, Questions Affecting the Admissibility of Scientific Evidence, 1970 U. ILL. L. REV. 1, 7 (1970).

179. 293 F. 1013 (D.C. Cir. 1923).

180. A nationwide survey of judges and attorneys showed that almost half of them encounter scientific evidence in at least one-third of their trials. Edward J. Imwinkelried, The Standard for Admitting Scientific Evidence: A Critique from the Perspective of Juror Psychology, 28 VILL. L. REV. 554, 554 (1983). The growth of crime laboratories has been one of the major factors leading to the appearance of new techniques in the courtroom. In 1966, there were 110 crime labs in the United States; ten years later, there were 240. Richard Saferstein, Criminalistics—A Look Back at the 1970s, A Look Ahead to the 1980s, 24 J. FORENSIC SCI. 925, 925 (1979).
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.  

Proponents of this “general acceptance” test have claimed that the test has the following advantages: 1) “those most qualified to assess the general validity of a scientific method will have the determinative voice”; 2) “a minimal reserve of experts [will exist] who can critically examine the validity of a scientific determination in a particular case”; 3) the test “may well promote a degree of uniformity in decision,” since judges with differing opinions on a technique may find that there is consensus in the scientific community; and 4) the lag time produced between scientific advances and the acceptance of new techniques into the courtroom helps counter a “misleading aura of certainty which often envelops a new scientific process, obscuring its currently experimental nature.”

If rigorously and specifically applied by the judiciary, the Frye test may certainly have these advantages; however, courts have applied the test selectively. Ironically, critics have attacked the test rather than the judiciary as the reason for this weakness in application. Critics claim that the Frye decision offered no guidelines and hence left too much room for maneuvering. The problem areas for judicial analysis are the following: designating the “particular field” in which a technique belongs, deciding whether both the theory and the technique

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181. 293 F. at 1014.
183. Id.
185. Id. at 32, 549 P.2d at 1245, 130 Cal. Rptr. at 149 (citing Huntington v. Crowley, 64 Cal. 2d 647, 656, 414 P.2d 382, 390, 51 Cal. Rptr. 254, 262 (1966)).
188. For instance, if a particular technique falls into many different fields and an expert from only one of those fields testifies as to the validity of the technique, the evidence may be rejected. See, e.g., People v. King, 266 Cal. App. 2d 437, 456, 72 Cal. Rptr. 478, 490 (1968) (voiceprint evidence rejected because the relevant fields of expertise were “anatomy, physiology, psychology and linguistics,” and the expert was not knowledgeable in all the areas). On the other hand, if the field is defined very narrowly, evidence produced by the
must be generally accepted, or just one or the other, and deciding if the technique has been generally accepted in the relevant field.

A more realistic look at the selective application of Frye shows that "many courts apply it as a means of justifying their own views about the reliability of the particular forensic techniques." These courts profess adherence to Frye, while simultaneously gutting the "general ac-

- technique can be admitted even if it would not be accepted by a larger community of experts. See, e.g., People v. Williams, 164 Cal. App. 2d Supp. 858, 862, 331 P.2d 251, 254 (App. Dep't Super. Ct. 1958) (although medical profession unfamiliar with the Nalline test for detecting narcotic use, test was admitted because it had "been generally accepted by those who would be expected to be familiar with its use"). Furthermore, there need not be unanimity of opinion as long as those who have had "direct and empirical" contact with the field accept the test. Commonwealth v. Lykus, 367 Mass. 191, 327 N.E.2d 671 (1975) (in upholding voiceprint evidence, the court rejected views of those who had only theoretical knowledge of the field).

- Many questions remain on this point: If empirical validation of a technique is enough to establish its validity, as with fingerprints and firearms identifications, how much empirical work is needed before it is considered valid? To what degree can the results be extrapolated to untested situations? Should validation studies be conducted by those who either developed the theory or possess a commercial interest in the technique? Id. at 1213.

- For the most part, courts do not separate theory from technique. When they do, they often ensure that the experts who testify are more than mere technicians. With polygraph evidence, for example, the courts require not only the polygraphist who performed the test to testify, but also an expert qualified to speak on the theory of the polygraph. Id. at 1214-15; see also People v. Kelly, 17 Cal. 3d 24, 39, 549 P.2d 1240, 1250, 130 Cal. Rptr. 144, 154 (1976) (voiceprint witness's expertise as a technician and law enforcement officer did not necessarily qualify him as a scientist in the field so that he could express an opinion as to its general acceptance).

- Some courts do not consider the testimony of one expert enough to establish general acceptance, especially if the expert has been a leading proponent of the technique and is therefore probably not impartial. See, e.g., id. at 37, 38, 549 P.2d at 1248, 1249, 130 Cal. Rptr. at 152, 153; Commonwealth v. Topa, 471 Pa. 229, 232, 369 A.2d 1277, 1282 (1977) (testimony of one expert on voiceprints not enough); People v. Tobey, 401 Mich. 141, 146, 257 N.W.2d 537, 539 (1977) (voiceprint evidence rejected because witnesses had built their careers and reputations on their voiceprint work and therefore were not impartial).

- It is possible to establish "general acceptance" based upon the literature in the field. See, e.g., People v. Palmer, 80 Cal. App. 3d 239, 252, 145 Cal. Rptr. 466, 472 (1978) (literature on gunshot residue evidence based upon scanning electron microscope analysis established general acceptance).

- Some courts have even considered prior judicial opinions relevant to general acceptance despite the fact that this undercut one of the rationales of Frye, namely to ensure that the most knowledgeable persons on the subject speak to the issue of reliability. See Giannelli, supra note 177, at 1218-19.

- As an example of a particular court's strategy, the Ninth Circuit characterizes the "particular field" broadly and states that both the technique and the underlying principle or theory must be generally accepted. Judicial recognition of the technique's reliability, however, still satisfies Frye. For a description of the Ninth Circuit's application of Frye, see generally Ronald S. Matthias, The Admissibility of Novel Scientific Evidence in the Ninth Circuit, 19 WILLAMETTE L. REV. 533 (1983).

189. See, e.g., United States v. Stifel, 433 F.2d 431 (6th Cir. 1970) (technique), cert. denied, 401 U.S. 994 (1971); United States v. Alexander, 526 F.2d 161 (8th Cir. 1975) (theory underlying technique); Reed v. State, 283 Md. 374, 391 A.2d 364 (1978) (theory underlying technique). One commentator suggests that the most crucial decision for courts using the Frye test is whether the theory has been generally accepted; once this is shown, courts will relax their standards to admit techniques. Strong, supra note 178, at 16-17. A different argument used to justify a technique's admissibility is that if the technique is generally accepted because it has been successfully applied, then the underlying theory must be valid even if it is not fully understood. Giannelli, supra note 177, at 1212.

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ceptance" standard by manipulating the "problem areas" to obtain the desired result.\textsuperscript{192} This empty adherence to the \textit{Frye} standard may be a purposeful strategy on the part of a judge who wants the evidence admitted despite the lack of proven general scientific acceptance. On the other hand, such empty adherence may also be the result of the fact that a judge hears only the selected information that an adversarial proceeding brings to the fore rather than the voice of the scientific community. The admission of DNA profiling evidence at \textit{Frye} hearings has most likely involved a little of both aspects of judicial decisionmaking.

2. Assessing DNA profiling under \textit{Frye}: What it should look like.

\textit{Frye} gives the scientific community, not the legal community, the last word on admissibility. What would a judicious assessment of the reliability of DNA typing under the \textit{Frye} standard look like? First, the court must decide in which "particular field" the DNA profiling technique belongs. The obvious categorical choices for DNA typing are molecular biology, genetics, population genetics, statistics, and forensics.

The problem in cases thus far has been the inherent bias in having those scientists that market the technique act as the spokespersons for the "particular field." In many of the cases involving DNA typing before \textit{Castro}, there were no expert witnesses for the defense, from which the court concluded there was general scientific acceptance,\textsuperscript{193} the main expert witnesses for the prosecution were the scientists from the private laboratories who had vested interests in the success and profits of their companies.\textsuperscript{194}

Analyzing biological evidence and testifying about it in court has

\textsuperscript{192} For instance, it is ironic that commentators on the admissibility standards herald Coppolino v. State, 223 So. 2d 68 (Fla. Dist. Ct. App. 1968), \textit{appeal dismissed}, 234 So. 2d 120 (Fla. 1969), \textit{cert. denied}, 399 U.S. 927 (1970), as the first case to reject \textit{Frye}, since the court claimed to be applying \textit{Frye}. See Giannelli, supra note 177, at 1293; David Dixon, \textit{The Admissibility of Electrophototheic Methods of Genetic Marker Bloodstain Typing Under the \textit{Frye} Standard}, 11 \textit{OKLA. CITY U.L. REV.} 773, 780 (1986) (student author). The court in \textit{Coppolino} admitted a toxicology test which could not have legitimately passed the "general acceptance" standard since it was designed specifically for the \textit{Coppolino} case.

\textsuperscript{193} For instance, in \textit{Spencer v. Commonwealth}, where the Virginia Supreme Court upheld the conviction and death sentence of Timothy Wilson Spencer based largely on DNA typing evidence, no defense experts testified in the pretrial hearings on the admissibility of the evidence and Spencer’s defense attorneys were unable to counter testimony that the procedure was generally accepted in the scientific community. Alan Cooper, \textit{DNA Case Is First Before a State High Court}, Nat’l J.J., July 3, 1989, at 14 (discussing \textit{Spencer v. Commonwealth}, Nos. 890096, 890097 (Va. Sup. Ct. 1989) (WESTLAW, Database VA-CS)). Likewise, no defense experts testified in \textit{Andrews v. State}, 533 So. 2d 841, 847 (Fla. Dist. Ct. App. 1988). In \textit{Cobey v. State}, the defense did not have experts and the court declared that "the trial judge did not err in finding that DNA fingerprinting was generally acceptable in the scientific community and in permitting its introduction into evidence, since there was no evidence to the contrary." 45 \textit{Crim. L. Rep.} (BNA) 2289, 2289 (Md. Ct. Spec. App. July 26, 1989). However, expert testimony in \textit{Castro} definitively showed that the scientific community was not unanimous.

\textsuperscript{194} For instance, Dr. Michael Baird, the Director of Paternity and Forensic Evaluation for Lifecodes, has become somewhat of a professional witness in Lifecodes cases. He testified to the admissibility of polygraph tests, which are routinely rejected as unreliable under \textit{Frye}. McCormick, supra note 187, at 884.
become an extremely lucrative business. Lifecodes representatives admitted that the ultimate objective of Lifecodes was not to do the testing, but to sell its probes, restriction enzymes, and training programs to crime laboratories in the U.S.195 Dr. Howard Cooke of the Medical Research Council in Edinburgh said that commercial pressures may be part of the reason private companies in the United States need to produce a result even when the evidence is of poor quality.196 Law Professor Barry Scheck, who represented Joseph Castro and is a member of the New York Governor's Commission on Forensic DNA Typing, testified before Congress in March, 1989:

[It] became a critical part of Lifecodes' marketing strategy to get into court first, before its competitors, so that its technology and reagents would gain an all-important competitive advantage—the judicial imprimatur of acceptability.

Soon Cellmark, whose Directors had expressed reluctance to begin forensic testing on a commercial basis, started to take cases, if only to protect its market share.197

The judiciary has unwittingly contributed to the making of an industry earning $40 million per year.198

The incentives for the private laboratories to get results that they can sell to a legal community eager to convict create examiner bias. The defense in Castro showed that Lifecodes did little to ensure against examiner bias, and, in fact, Lifecodes exacerbated the chance of error with such practices as visual lane-to-lane comparisons and matching rules that underestimated the probability of a random match.199 The defense alleged outright "scientific fraud" in at least one instance,200 and alleged misrepresentations and evasions in many others where Dr. Baird of Lifecodes reversed himself once his unfounded conclusions were exposed.201

Since the scientists from the private laboratories who perform the

in all three of the cases that will be discussed in this note. See notes 223-254 & 311-327 infra and accompanying texts.

195. Scheck Testimony, supra note 59, at 1-2; see Unger, supra note 29, at 47.
197. Scheck Testimony, supra note 59, at 2. See notes 107-121 supra and accompanying text.
198. See Unger, supra note 29, at 47. Lifecodes claims that it will be a $100 million per year business within five years or less; the company also plans to get into the business of banking DNA profiles of convicted sex offenders for California and Colorado. Cetus is currently a $20 million per year business and predicts its profits will rise to $60 million per year in the next two or three years. Id.
199. See notes 107-121 supra and accompanying text.
200. Castro Defense Brief, supra note 96, at 38. The defense claimed that Lifecodes redefined its data to place the Hispanic population in Hardy-Weinberg equilibrium. See text accompanying notes 141-143 supra.
201. Castro Defense Brief, supra note 96, at 100-08. The defense stated that when interpreting the autoradiographs, "Dr. Baird not only disagreed with the other prosecution experts, but he could not even be internally consistent. If it weren't for the fact that peoples' [sic] lives depend on the reliability of the forensic lab's ability to identify bands, this scenario might
test must necessarily testify about the accuracy of their results and will “naturally paint a rosy picture of the test and its accuracy.” They are not necessarily the ones who should testify on the overall reliability of the technique. Frye contemplated the testimony of impartial experts. Although prosecutors have had “unbiased” experts in the broad fields of genetics and molecular biology testify to the general acceptance of the DNA typing techniques that they use in diagnostics and general research, as Part I of this note explained, general acceptance in diagnostics says little if anything about the reliability of the technique as applied to forensics. No one has testified who is both impartial and qualified to assess the reliability of a forensic technique, whose norm is the one-time testing of old and dirty samples. Thus the prosecution’s case has left a yawning gap in the analysis of general acceptance. The gap will not be filled until the scientific community examines the technique in accordance with the proposal in Part I.

After deciding the relevant fields, the second issue for a court applying Frye is whether the principles, the technique, or both should be generally accepted. The experience of Castro makes clear the need for accepting both. Accepting only one or the other is a way to manipulate Frye to admit unreliable evidence. With DNA profiling, experts agree that there is nothing wrong with the technique in principle, but they disagree on the reliability of the technique in practice, as applied to forensics. The courts must scrutinize the particular application at issue. As Part I demonstrated, acceptance of the DNA typing technique in research and diagnostics does not translate into acceptance of the technique as applied to forensics. To ignore this when deciding general acceptance is to frustrate the purpose of Frye altogether.

The final issue the court must address is whether the relevant scientific community has accepted the technique. One measure of general scientific acceptance is publication of the technique in peer-reviewed scientific journals. Testimony in Castro demonstrated that reliance on this factor can be problematic. Lifecodes has published several articles, but those articles have not covered some of the more controversial aspects of the technique. For instance, a validation study Lifecodes published did not involve contaminated samples. Also, some of the

Perhaps the most striking example of equivocation was when Dr. Baird changed his mind several times as to the source of the control sample in the test run to determine the sex of the owner of the blood on Castro’s watch. See text accompanying notes supra. 202. Burk, supra note 3, at 468. 203. See note 190 supra. 204. See Thompson & Ford, supra note 17, at 55-57. 205. See text accompanying notes 167-174 supra. 206. See note 189 supra. 207. See note 53 supra. 208. See note 190 supra. 209. See Alan Giusti, Michael Baird, Sam Pasquale, Ivan Balazs & Jeffrey Glassberg, Ap-
techniques discussed in Lifecodes's articles have been refuted. For instance, the peer reviewer of Lifecodes's published article on allele frequencies testified in Castro that the findings in the article were unreliable.\textsuperscript{210} Furthermore, Lifecodes did not adhere in practice to its published procedures for computerized matching and for methods of determining allele frequencies in its database.\textsuperscript{211} Scientists understand publication as only the first step towards general scientific acceptance. Publishing provides the scientific community with an opportunity to reproduce the results.\textsuperscript{212} The more reproducible the results,\textsuperscript{213} the more reliable the technique employed. Wide publication by scientists in the related fields, and thus wide validation of results, avoids the pitfalls of self-validation by a small group.\textsuperscript{214}

Because the three private laboratories conceal much of their process from the public view with the shield of "trade secrets," their techniques cannot gain general acceptance in the scientific community. The scientists from these labs have not publicly revealed much of their protocols through publishing.\textsuperscript{215} On the individual case level, some defendants have not been allowed access to the laboratory documents.\textsuperscript{216} If during trial opposing experts have been allowed to review the protocols, the experts must sign agreements not to disclose them.\textsuperscript{217} Therefore, independent validation has not been possible. The private labs have also restricted access to their probes. The lack of universal availability of the probes in the scientific community means both the inability to reproduce results and the frustration of a shared attempt to build a large database of allele frequencies for particular probes.\textsuperscript{218} Clearly, scientific acceptance cannot occur with proprietary rights restricting access to the technology.
In addition, it is erroneous for courts to substitute the frequency of the use of a novel technique or its admission at trial for an analysis of its general acceptance. As an example of this reasoning, when the press reporting on Castro asked Lifecodes about the reliability of its test, a spokeswoman responded, “Our DNA technology already has been accepted in over 100 trials in this country and that’s proof that it is considered valid and reliable technology.”219 This statement merely reveals that the courts may be going forward with the acceptance of this technique without the scientists. The appropriate scientific community has not been invited to scrutinize the results. Judges have been misled by mere use of a technique in the past.220 Inferring the technique’s general acceptance from the fact that some courts have admitted DNA evidence221 only compounds ignorance about the technique, and it guts the Frye test entirely.222

3. **Assessing DNA profiling under Frye: What it looks like in Wesley and Castro.**

Two cases in which courts have been confronted with DNA profiling evidence illustrate how courts have misunderstood or misapplied the Frye standard.

In **People v. Wesley**,223 the court appeared enamored with the prospect of admitting into evidence a technique on the “cutting edge” of forensic science—one that will “constitute the single greatest advance in the ‘search for truth,’ and the goal of convicting the guilty and acquitting the innocent since the advent of cross-examination.”224

The court placed the technique in the fields of molecular biology, genetics, chemistry, biology, biochemistry, and population genetics.225 Misapplying the Frye test, the court stated that since the underlying principles and technology were uncontested by any of the expert wit-
nesses, Frye was satisfied despite the fact that an unbiased expert with personal knowledge of and experience with the forensic application was not present. The court eliminated the step of proving general acceptance of the forensic application, stating that defense arguments against the application of the technique in this case went to weight and not admissibility. The court was satisfied that proper application of the technique to forensics may be possible because the technology exists to do so, but the mere possibility of proper application is not the same as having the proper application in place. Only after scientists have shown that they can reproduce results in the forensic technique should the courts move the focus of the analysis away from Frye admissibility questions to questions of weight, i.e., whether the accepted steps were followed in an individual case.

The credentials of the prosecution’s experts apparently overwhelmed the court. The experts were the best and the brightest that state money could buy, and their credentials obscured critical analysis of the substance of their testimony. The court used glowing adjectives to describe the prosecution experts and believed that the experts’ experience with the techniques as performed in diagnostics answered the question of the reliability of the technique as performed in forensics. Interestingly, the court disparaged the defense experts.

The court relied heavily on statements by Dr. Roberts, which were later discredited in Castro. Dr. Roberts, of course, recanted his opinion on the reliability of Lifecodes’s methods in Castro, where he joined in the statement by the defense experts. Dr. Roberts told the court in Wesley that it was impossible to get a false positive with Lifecodes’s test; instead, the autoradiograph would be blank if any steps were performed in an individual case.

226. The defense experts included Dr. Neville Colman, Associate Professor of Pathology at Mt. Sinai School of Medicine, and Dr. Richard Borowsky, Associate Professor of Biology at New York University. Among the prosecution experts were Dr. Richard Roberts, Assistant Director of Research at Cold Spring Harbor Laboratory; Dr. Kenneth Kidd, molecular biologist and population geneticist at Yale University School of Medicine; Dr. Michael Baird, Director of Paternity and Forensic Evaluation for Lifecodes; and Dr. Sandra Nierzwicki-Bauer of Rensselaer Polytechnic Institute. Id. at 648, 651, 654, 655, 657.

227. Id. at 650.

228. See Thompson & Ford, supra note 17, at 102-06 (analyzing Wesley).

229. One commentator explained that expert testimony has two components, the “message” component, which is the actual words verbalized by the expert, and the “paramessage” component, which encompass all elements that are not a part of the literal testimony, such as gestures of the expert, credentials, and prestige. The danger is that the triers of fact will be influenced by the paramessage when they do not understand the message. Steven M. Egesdal, The Frye Doctrine and Relevancy Approach Controversy: An Empirical Evaluation, 74 GEO. LJ. 1769, 1771, 1790 (1986) (student author).

230. For instance: “Dr. Colman’s concern was with whether or not the laboratory procedures, methodology, and quality control used by Lifecodes were adequate to assure the accuracy and reliability of its testing results. He thought not! However, on every point raised by him he was overwhelmingly refuted—both by the facts and by the opinion of experts with superior qualifications and experience.” People v. Wesley, 533 N.Y.S.2d 643, 651 (1988).

231. See note 63 supra and accompanying text.
formed improperly.\textsuperscript{232} This assertion was proven wrong in \textit{Castro}, where the experts demonstrated that contamination could produce a false positive.\textsuperscript{233}

Dr. Roberts also peer-reviewed for trial Lifecodes’s article on allele frequencies and population genetics, which it had not yet published. Dr. Roberts told the court that the methodology was sound.\textsuperscript{234} Although defense expert Dr. Borowsky objected that the population genetics article did not supply the raw data Lifecodes used to determine whether the particular population studied was within Hardy-Weinberg equilibrium,\textsuperscript{235} the court was unconcerned since the “eminent” Dr. Kidd testified that raw data is usually not published in articles in order to “conserve journal space.”\textsuperscript{236} However, in \textit{Castro}, Dr. Green, who did the actual peer review of this article before publication, testified that he would not have accepted it for the \textit{American Journal of Human Genetics} if he had known that Lifecodes had improperly adjusted its data, and that the population was not in Hardy-Weinberg equilibrium.\textsuperscript{237} The \textit{Wesley} court did, however, reduce the probability statistic for each test by a factor of ten to offset possible Hardy-Weinberg disequilibrium and promote due process.\textsuperscript{238} However, due process surely requires more than such ad hoc, unscientifically-based adjustments by courts.

Finally, the court was persuaded that the forensic technique used by Lifecodes was “generally accepted” in the relevant scientific community based on testimony that was only marginally related to the forensic DNA typing technique: Dr. Nierzwicki-Bauer, in an article on identification of blue-green algae using restriction fragment length polymorphisms, described her use of the same procedures as the ones used at Lifecodes;\textsuperscript{239} Dr. Baird of Lifecodes testified that Lifecodes uses procedures approved by the Parentage Testing Committee of the American Association of Blood Banks;\textsuperscript{240} and Dr. Roberts claimed that if he were to set up such a lab, he would use the same procedures as those used by Lifecodes.\textsuperscript{241} Thus, the court based the acceptance of a forensic technique on the reliability of testing performed on algae, committee approval of the testing procedures as applied to paternity tests, which involve whole blood samples and built-in controls, and a hypothetical situation. Misled by the absence of unbiased testimony on the general acceptance of the forensic test, the court concluded that

\begin{itemize}
  \item \textsuperscript{232} \textit{Wesley}, 533 N.Y.S.2d at 652.
  \item \textsuperscript{233} \textit{See} text accompanying notes 68-74 \textit{supra}.
  \item \textsuperscript{234} \textit{Wesley}, 533 N.Y.S.2d at 652-53.
  \item \textsuperscript{235} \textit{Id.} at 657.
  \item \textsuperscript{236} \textit{Id.} at 658.
  \item \textsuperscript{237} \textit{See} text accompanying notes 141-144 \textit{supra}.
  \item \textsuperscript{238} \textit{Wesley}, 533 N.Y.S.2d at 659 & n.26.
  \item \textsuperscript{239} \textit{Id.} at 656.
  \item \textsuperscript{240} \textit{Id.} at 654.
  \item \textsuperscript{241} \textit{Id.} at 652.
\end{itemize}
"DNA Fingerprinting was merely the commercialization of long-established scientific principles."\(^{242}\)

In the pretrial hearing in *People v. Castro*,\(^ {243}\) the New York Supreme Court fell into the same dark hole. Like the *Wesley* court, it also viewed the *Frye* test as not encompassing the verification of the specific application of the technique to forensics. Rather, it posited that the *Frye* test encompassed only two questions: 1) "Is there a theory, which is generally accepted in the scientific community, which supports the conclusion that DNA forensic testing can produce reliable results?,"\(^ {244}\) and 2) "Are there techniques or experiments that currently exist that are capable of producing reliable results in DNA identification and which are generally accepted in the scientific community?"\(^ {245}\) Defense expert Dr. Lander responded in the negative to the court's second question, since "[a]lthough all the procedures start from standard protocols of molecular biology, there is no consensus on how to overcome the unique problems of DNA Identification."\(^ {246}\)

The defense attorneys protested the court's formulation of the *Frye* test. They pointed out that the second question "deviates from the traditional legal notion of 'case and controversy.'"\(^ {247}\) They noted that *Frye* commands that the procedures actually employed by Lifecodes be evaluated, not procedures that could be developed or might exist in some research laboratory but have never been tested in forensic analysis.\(^ {248}\)

Despite the valid protestations of the defense, the court stuck to its new formulation of *Frye*. This reformulation of the test allowed the court to reach the erroneous conclusion that the DNA forensic identification evidence met the *Frye* standard.\(^ {249}\)

The court did, however, add a third question to the test for admissibility in a given case: "Did the testing laboratory perform the accepted scientific techniques in analyzing the forensic samples in this particular case?"\(^ {250}\) Unfortunately, this question cannot be properly answered since the court omitted the crucial step of deciding if there are accepted scientific techniques for forensic DNA profiling. However, Dr. Lander ventured to answer it anyway, responding, "Even before procedures for

\(^{242}\) Id.

\(^{243}\) No. 1508/87 (N.Y. Sup. Ct. 1989).

\(^{244}\) Castro Admissibility Decision, supra note 62, at 6.

\(^{245}\) Id.

\(^{246}\) Lander's Castro Report, supra note 53, at 36.

\(^{247}\) Castro Defense Brief, supra note 96, at 6.

\(^{248}\) Id.

\(^{249}\) See Castro Admissibility Decision, supra note 62, at 26, 37. The court used sleight of hand to reach its miraculous conclusion. It stated that defense experts Drs. Lander and Flaherty acknowledged that the test would be in a position to generate reliable results in approximately six months, but the court said this opinion could only be valid if the techniques for doing so exist now, and thus, "to breathe any meaning into the opinion of these highly respected and rather brilliant scientists one must conclude that the test is presently reliable and will remain so for the next six months." Id. at 27.

\(^{250}\) Id. at 6.
DNA Identification have been generally accepted by the scientific community, it is possible to recognize that much of the procedure developed by Lifecodes deviates so far from accepted norms in molecular genetics that it could never gain general acceptance in the scientific community.”

Ultimately, in answering this third question, the court decided to exclude the evidence of a match. However, it most likely based this decision on the fact that the prosecution and defense experts together signed a statement that the evidence was unreliable and left the court little choice but to agree. On the other hand, when the prosecution experts did not agree on a particular issue, the court intimated that it would let the jury decide among the conflicting expert opinions. Yet if the prosecution experts appeared to agree among themselves on a point, such as on the possibility of declaring matches visually, the court proclaimed acceptance by “the scientific community.” The court obviously favored the promotion of the use of novel scientific evidence by prosecution experts.

The court apparently felt that the courtroom forum is equipped to evaluate the DNA typing test since the autoradiographs “firmly memorialize the experiments conducted. Therefore, they can be reviewed, in an adversarial proceeding, to insure that the proper scientific procedures were performed.” This statement exhibits the court’s lack of understanding about the intricacies of the procedure and about how much of the procedure goes unreviewed when a defense expert must come in after the testing is complete. Frye hearings are “a blunt instrument for carving careful technical distinctions.” Courtroom proceedings are not a proper substitute for extensive laboratory experimentation when determining truth in science.

B. DNA Profiling Fails the Relevancy Test

1. Characteristics of the relevancy test.

The Federal Rules of Evidence, adopted in 1975, although not explicitly overruling Frye, endorse a relevancy standard for all kinds of

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253. Id. at 34.
254. Id. at 28.
255. Lander Testimony, supra note 24, at 6.
256. Courts and commentators are divided over whether the Federal Rules of Evidence superseded Frye. See P. Giannelli & E. Imwinkelried, supra note 15, at 28 n.128. Weinstein and Berger claim that “Rule 702’s failure to incorporate a general scientific acceptance standard, and the Advisory Committee[’s] failure to even mention the Frye case must be considered significant. The silence of the rule and its drafters may arguably be regarded as tantamount to an abandonment of the general acceptance standard.” Jack B. Weinstein & Margaret A. Berger, Weinstein’s Evidence ¶ 702(03), at 702-36 (1988), while Professor McCormick states that Frye is not an appropriate inquiry under the federal rules, Charles T. McCormick, Law of Evidence § 203, at 415-17 (1954).
evidence: Rule 401 defines "relevant evidence"; Rule 402 states that relevant evidence is generally admissible; Rule 403 states that relevant evidence may be excluded on the grounds of prejudice, confusion or waste of time; and Rule 702 generally allows experts to testify on anything that will help the trier of fact. As applied to novel scientific evidence, these rules together provide a much lower threshold of admissibility than the "Frye" standard, since the evidence would only be subject to a relevancy-type balancing test of probative weight against prejudicial effect.

As courts abandon "Frye" and flock to the relevancy standard, their distaste for deferring to the scientific community the decision on the reliability of novel scientific evidence becomes apparent. In United States v. Williams, the court explicitly rejected "Frye" and admitted spectrographic voice analysis, a technique that had received mixed reviews from the relevant scientific community. The court concluded that the reliability of scientific evidence cannot be determined "solely on a process of 'counting (scientific) noses,'" and that "the courts cannot . . . surrender to scientists the responsibility for determining the reliability of that evidence." One general rationale behind courts' abandonment of the "Frye" test appears to be that "it is better to admit relevant scientific evidence in the same manner as other expert testimony and allow its weight to be attacked by cross-examination and refutation."

257. Professor McCormick was the early leader in stating a preference for a relevancy standard:

"General scientific acceptance" is a proper condition upon the court's taking judicial notice of scientific facts, but not a criterion for the admissibility of scientific evidence. Any relevant conclusions which are supported by a qualified expert witness should be received unless there are other reasons for exclusion. Particularly, its probative value may be overborne by the familiar dangers of prejudicing or misleading the jury, unfair surprise and undue consumption of time.

C. McCOmMICK, supra note 256, § 171, at 363-64.

258. "Relevant evidence" means evidence having any tendency to make the existence of any fact that is of consequence to the determination of the action more probable or less probable than it would be without the evidence." FED. R. EVID. 401.

259. "All relevant evidence is admissible, except as otherwise provided by the Constitution of the United States, by Act of Congress, by these rules, or by other rules prescribed by the Supreme Court pursuant to statutory authority. Evidence which is not relevant is not admissible." FED. R. EVID. 402.

260. "Although relevant, evidence may be excluded if its probative value is substantially outweighed by the danger of unfair prejudice, confusion of the issues, or misleading the jury, or by considerations of undue delay, waste of time, or needless presentation of cumulative evidence." FED. R. EVID. 403.

261. "If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise." FED. R. EVID. 702.

262. 583 F.2d 1194 (2d Cir. 1978), cert. denied, 439 U.S. 1117 (1979).

263. Id. at 1198.

264. Id.

sumption of this rationale is that juries can understand the techniques and therefore shielding them to prevent prejudicial effects is not necessary. However, as this note will demonstrate, this is not always the case.266

The Williams court identified five reliability indicia: 1) the potential rate of error in use of the technique; 2) the existence and maintenance of standards among its users; 3) the care with which the technique was employed in the case and whether the technique lends itself to abuse; 4) the analogy of the technique to others whose results are admissible; and 5) the presence of safeguards in the characteristics of the technique.267 After taking these factors into account the court employed the traditional relevancy balancing approach weighing these measures of reliability against any tendency for the evidence to mislead the jury. This note will use the Williams approach to evaluate whether DNA profiling evidence should be admitted under the relevancy standard.

2. Assessing DNA profiling under the relevancy test: What it should look like.

Probative value. The first part of the relevancy test is a measure of the probative value of the evidence proffered. Using the five Williams indicia, the DNA profiling technique as it currently is practiced is not reliable. Moreover, the indicia themselves are misguided and further manifest the courts' ignorance in or avoidance of what constitutes actual scientific reliability.

As for the first reliability indicia, the potential rate of error in the forensic DNA typing technique is unknown.268 The many complex steps involved in this test leave numerous possibilities for undetectable errors. The tester cannot know that something has gone wrong until the uniform controls and standards recommended by a scientific working committee are in place as proposed in Part I. This is especially true when calculating the statistical probability of a coincidental match, where at this stage "rate of error" could only be a subjective determination since there is considerable disagreement over the proper standards. One method of determining overall rate of error is to do frequent blind proficiency testing. This process has only been done once, and because the labs were simply required to determine if there

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on Evaluating the Weight of Scientific Evidence, 23 Wm. & Mary L. Rev. 261 (1981) (discussing the need for the adversary system to focus on ways to attack the weight of scientific evidence rather than admissibility since more courts are admitting scientific evidence).

266. See Giannelli, supra note 177, at 1240 ("Considering the techniques that may be involved—neutron activation analysis, atomic absorption, and ion microprobic analysis—the assumption of jury capability provides a shaky foundation upon which to construct an approach to admissibility of novel scientific techniques.").

267. 583 F.2d at 1198-99.

268. In diagnostics, where the conclusions drawn are considered reliable due to the limitation of possibilities to four known alleles per person, there is still an error rate of roughly 2.5%. Lander's Castro Report, supra note 53, at 4.
was a match, they had a 50 percent chance of guessing correctly. As the "no false positives" mystique has been discredited by Castro, any quoted rate of error coming from the private laboratories should be regarded with caution and skepticism.

Next, although the practitioners of DNA profiling maintain standards, if their internal standards are not accepted in the scientific community as reliable, DNA profiling fails to meet the second Williams criterion. Until the relevant scientific and forensic communities have agreed on uniform standards, the mere existence of standards within each laboratory is not very meaningful.

One part of the third factor, the care with which the technique was performed in the particular case, must be determined through case-by-case examination. One problem with this factor in DNA typing is that the prosecution's expert witness will simply describe an amazing number of steps which will appear to a jury to constitute due care. Hence, a second related problem is that the burden of proof will in essence be shifted onto the defendant to counter that assumption of care. Thus, the ability of the often indigent defendant to locate and hire an expert witness becomes paramount. Furthermore, the defense's witness has the extreme disadvantage of coming in after the test is done, and can only check the records the lab discloses and the autoradiographs, which may not readily reveal errors that led to a false match.

The second part of this third factor, whether the technique lends itself to abuse, was probably designed to monitor any subjective determinations made by the tester. For instance, the method of examiner questioning in polygraphy may lend itself to abuse. The possibilities for examiner bias in Lifecodes's method of DNA testing as exposed by Castro testimony makes it particularly suspect.

The fourth Williams factor, analogies to the reliability of other techniques, serves as an unfair substitution for the reliability of the technique at issue. For instance, although protein gel electrophoresis and DNA profiling are very different techniques, they both fall within the field of genetics and both analyze dried blood and semen with a great degree of specificity. Therefore, they are probably most "alike" in terms of analogies, yet the procedures involved are entirely different. Protein gel electrophoresis was initially accepted as reliable in the courts, but then was discredited and rejected by some courts.

269. See notes 163-165 supra and accompanying text.
270. This burden is unfair given the indigent defendant's lack of resources, and impedes the defendant's constitutional right to an adequate defense. See notes 335-338 infra and accompanying text.
271. See notes 109-116 supra and accompanying text.
272. Indeed, gel electrophoresis in DNA typing and protein gel electrophoresis are often confused with each other. See text accompanying note 320 infra.
273. The technique was used in thousands of cases in the late 1970s and was accepted by courts in several states. However, its reliability came under attack and the test was rejected in
Since it has not been completely rehabilitated as a reliable technique, can one surmise that DNA profiling is also not reliable? The proponents of DNA profiling surely would answer no. Once protein gel electrophoresis is widely accepted, should it weigh in the balance then toward acceptance of DNA profiling, an entirely different technique? Surely not. If anything, perhaps the courts should analogize to the tortuous history of the admissibility of protein gel electrophoresis evidence and ask themselves if something is wrong with an admissibility standard that admits unreliable evidence.

Analogies may work relatively well in legal analysis, where precision is not as crucial as the creation of cohesive and logical categories of law which serve to aid people in ordering their actions. However, analogies are simply not a satisfactory mode of scientific analysis, which depends on the integrity of each individual result.

Applying the final Williams factor, there are no safeguards present in the DNA test itself. Although paternity testing and diagnostic research have built-in controls in comparing the DNA profiles of the parents to that of the child, forensic samples are of unknown origin and thus have countless numbers of possible alleles. Therefore, all of the controls for the forensic test must be imposed from the outside.

Prejudicial effect. Even if a court took a more casual approach to the probative value of the evidence and decided that in a particular case, the evidence of a match at least made it "more probable" that the accused was the perpetrator, the DNA typing technique is still more prejudicial than probative.

A jury cannot weigh DNA typing evidence. If and when jurors hear of and see the DNA test results, they will most likely not second-guess the testifying expert’s conclusion. Excerpts from Andrews v. State, the first case in the country to have the admissibility of DNA typing evidence upheld on appeal, illustrate the testimony a jury will typically encounter. There were no defense witnesses in Andrews. Essentially, the scenario unfolds as follows: The prosecution’s expert witness with numerous credentials and years of experience is sworn; the expert ex-


274. Recently, proponents of the evidence have had some success reestablishing the admissibility of the technique. See Thompson & Ford, supra note 17, at 47 & n.15. See generally Dixon, supra note 192.

275. See note 98 supra.

276. The "more probable" relevancy standard should not be applied to admissibility of DNA typing evidence in criminal cases. After the prosecution has met this low burden of proof, then the burden of proving unreliability at trial falls heavily and unfairly on the defendant, who is typically without resources. See note 270 supra; text accompanying notes 328-346 infra; note 348 infra and accompanying text.


plains in simplistic language the elements of biology and experimentation:

Q: Could you explain to the jury what genetics means?
A: Well, really genetics is involved with heredity. And when you're talking about genetics you're talking about the process that makes each one of us unique. And when each one of us is conceived, part of your genetic material is derived from your biological mother and part from your biological father.  
Q: And what is a reagent?
A: A reagent is just a material that you use to do a test. You can almost think of it like cooking, so a reagent would be butter or eggs or flour.

Next the expert explains how the test was done, with big colorful diagrams of the double helix unzipping and zipping:

Q: Now, the day comes to do the test. What's done first?
A: The first thing that is done is the evidence is examined to see what type of material we have, be it bloodstain, a semen stain, whatever the nature of the evidence is.

Once we do that, the next process is to isolate the DNA from that. You can think of DNA as kind of like a nut locked within a shell. So the first step we do is to break open that shell and to isolate the DNA away from the other material in a cell.

Sometimes even the expert is at a loss to come up with a simplistic analogy to explain an aspect of the technique:

Q: How exactly does that work without getting too technical, is there something you can compare it to?
A: Offhand nothing comes to mind.

Finally, the expert explains that the DNA pattern is like a supermarket bar code, and that if the two supermarket bar codes are the same, there is a match; the expert shows the jury the autoradiographs, tells them to see for themselves, and erroneously leads them to believe it is impossible to call a false match:

Q: Okay. Nothing can go wrong to give you a false pattern?
A: There's really no way to generate an alternative pattern to the one that's in the DNA. It's in there. It's like the shape of this building, let's say, and you either see the building in it's [sic] shape or you don't. It's not like you can suddenly walk out there and see it and it looks like the Empire State Building instead of this courthouse. It looks the way it looks.
On cross-examination, the defense attorney, who has recently revived his knowledge of Watson and Crick from high school biology, feels unevenly matched:

Q: The last thing in the world I want to do is get into a scientific argument with you because I know what the end result of that would be?
A: Yes.284

Without his own expert to refute bald statements of accuracy by the prosecution's experts, sneaking in a clever rejoinder is sometimes the only resort of the defense attorney:

Q: The basic proposition of your opinion, however, is that the test can't be wrong. You get a result or no result, but it can't make a mistake?
A: It's like a photograph, you know. I mean, you can either get a photograph that develops and prints or it doesn't. And either it looks like you or it doesn't. But it can't suddenly come out looking like Tim Berry.
Q: You haven't seen some of the fuzzy photographs that I've taken.285

Nevertheless, the defense attorney makes a valiant attempt to show to the jury that the technique is not quite so simple and that there are many possibilities for error. However, his questions about protocol and controls sound nitpicky, get lost in a mire of details and confusion, and are not as interesting to the jury as the lesson in genetics they just received286:

Q: If any part of that powder either dissolved improperly or caused by inadequate mixing, there would be some inconsistency in the gel solution itself, [sic] would it not be possible for that inconsistency in the gel solution to exist in one, I'll call it a lane of the track or one band down and miss your standards, unlikely but possible?
A: It is possible, yes.
Q: And if it hit one of those tracks and did not hit the standards, the standards would still run as they always had, would they not?
A: Yes, they would.
Q: And yet it might make some difference in the speed through which the material in the other tracks made its way through the agarose gel?
A: That is possible.287

On redirect, the prosecutor simply has the expert reiterate that the

284. Id. at 485-86 (cross-examination of Housman).
285. Id. at 488. Actually this retort is fairly appropriate since the banding patterns are often fuzzy and difficult to interpret. See text accompanying notes 75 & 78 supra.
286. "We all felt like we were back in science class," said one juror after hearing testimony on the principles and mechanics of DNA typing at the trial of Tommie Lee Andrews. Lewis, supra note 58, at 52.
experiment went well and that a match was declared. The defense attorney's obtuse questioning is lost on the jury:

Q: In this test we're testifying here today about, did any of the equipment malfunction?
A: No.
Q: Any problems at all?
A: No.
Q: Did all the equipment work properly?
A: Yes.
Q: None of the quality control people ever came to you and said there's a problem, Alan?
A: No.288

Cross-examination in the Andrews case did not provide a sufficient counter to the overly simplistic and misleading explanations of an incredibly complex process.289 For instance, prosecution experts Dr. Housman and Dr. Baird visually examined the autoradiograph in front of the jury,290 and then told the jury that the DNA in the semen sample was the same as that of the defendant.291 This is an erroneous assertion. The only thing that the experts could definitively say after an examination of the autoradiograph was that there was a match, not that the samples came from the same source. Such an inaccurate statement renders the cursory testimony about the size of the population database and the calculations of a probability of a random match in the population292 meaningless to the jury in comparison. Furthermore, cross-examination on this point was ineffective since the defense attorney understandably did not have the extensive knowledge of population genetics necessary to argue that the database was perhaps not in Hardy-Weinberg equilibrium or that application of the product rule may have been inappropriate. But even a defense expert's testimony will not provide the jury with the requisite genetics background to evaluate potentially conflicting testimony.

Although several studies have been conducted on juror understanding of scientific evidence, none has focused on a technique as technical as DNA fingerprinting.293 One survey of the various studies of juror

288. Id. at 454-55 (redirect of Giusti).
289. One article reported that the technique as it is performed by Lifecodes takes about eight weeks to complete and involves about 200 steps. Milena Jovanovitch, Valhalla Lab Specializes in New Forensic Test, N.Y. Times, Dec. 11, 1988, at 1, col. 1.
290. The visual examinations in the courtroom are misleading to the jury, which might conclude that on-the-spot visual determination of a match is possible or that it is possible for them to do it as well. The jury appeared to take this false lead, as one reporter on Andrews wrote, "Concentrating intently, the jury compared the DNA band patterns in one column with the band patterns in the next, figuring out the test results for themselves." Lewis, supra note 58, at 52.
291. Direct of Baird, supra note 134, at 500; Direct of Housman, supra note 283, at 477.
292. See Andrews Record, supra note 134, at 508-23.
293. For examples of studies on the ability of juries to handle scientific evidence, see generally Egesdal, supra note 229 (quoting studies which show jurors not overly impressed by
psychology reaches the perhaps intuitively obvious conclusion that jurors are not overwhelmed by novel scientific evidence if they understand the testimony, but can be overly impressed if they do not.\textsuperscript{294} Since the experts testifying in \textit{Andrews} grossly oversimplified the technique, some jurors may have thought they understood the technique since they more or less followed the prosecution expert’s explanation, but most of them were not equipped to critique or doubt that explanation.

A \textit{Science} magazine writer reporting on the trial of Randall Jones in Florida was impressed that, despite the complex process of DNA typing, “the scientific testimony at the Jones trial apparently did not faze the jury. It brought in a guilty verdict—with a recommendation for the death penalty—in 12 minutes flat.”\textsuperscript{295} It is more likely that the jury believed unquestioningly what the prosecution experts told it. The prosecutor in the case said, “When you put the x-ray films on a light box, anybody can see the match.”\textsuperscript{296} If a prosecutor with more knowledge of the technique than the jury can make such a misleading statement, surely it is improper to expect a jury to comprehend and effectively evaluate the technique’s evidential value. The trial of Victor Lopez, the first man in New York State to be convicted with the help of DNA typing evidence, illustrates this point. After the trial, one juror said, “The DNA was kind of a sealer on the thing. You can’t really argue with science.”\textsuperscript{297} The jury forewoman told a \textit{Newsday} reporter, “That was the only thing that opened my eyes. That was the whole case, in my opinion.”\textsuperscript{298} These jurors were in no position to reject evidence as exciting and as intimidating as DNA typing. They could not be expected to realize that “science” can often be erroneous in the formative stages of a new technique.

Even if scientists were to agree in the future that the DNA profiling technique is completely reliable and thus there was no longer as much danger in presenting the evidence of a match to the jury, the introduction of statistical evidence at trial will remain problematic. There is evidence that juries cannot weigh statistical evidence correctly and that juries come to different conclusions depending on the presentation of the evidence. For instance, juries often erroneously equate the frequency of the accused’s blood type in the population with the probability of innocence, discounting the other evidence in the case pointing to guilt or innocence,\textsuperscript{299} such as the fact that a close relative is

\begin{itemize}
\item polygraph evidence, voiceprint evidence, fingerprints, or handwriting samples); Imwinkelried, supra note 180 (no objective data to support fear that jurors cannot understand scientific evidence).
\item 294. Egesdal, supra note 229, at 1788, 1790.
\item 295. Marx, supra note 5, at 1616.
\item 296. Id.
\item 298. Michaud, supra note 14, at 73.
\item 299. William C. Thompson & Edward L. Schumann, Interpretation of Statistical Evidence in
\end{itemize}
also suspected.\textsuperscript{300} This type of fallacious reasoning is demonstrated in a study in which physicians who were told that there was a 90 percent chance a particular test would be positive \textit{if the patient had a tumor} erroneously concluded that there was a 90 percent chance the patient had a tumor if the test result was positive.\textsuperscript{301} Prosecutors use this tendency to their advantage by having forensics experts present the statistic in terms of the probability the defendant would have the characteristic \textit{if he were innocent}\.\textsuperscript{302}

In the past courts have rejected statistical evidence as more prejudicial than probative.\textsuperscript{303} In People v. Collins,\textsuperscript{304} the prosecution sought to prove that a certain couple committed a robbery by estimating the likelihood of a black man with a beard and a mustache riding in a partly yellow automobile alongside a white girl with a blond ponytail.\textsuperscript{305} The prosecution suggested that the statistical odds of another couple with the same characteristics committing the crime were 1 in 12 million.\textsuperscript{306} The court easily rejected the assumptions underlying the statistic and the use of the product rule where the probabilities were so obviously interdependent.\textsuperscript{307} As long as the independence of the alleles located by the probes in DNA profiling remains questionable, the use of the product rule in DNA profiling is just as misleading as in Collins. In fact, the two cases are more similar than meets the eye—if there is a white skin/blond hair dependency as noted in Collins, it is the physical manifestation of two linked alleles.

The rationale for rejecting the use of statistics is that it confuses juries about their duty to decide guilt or innocence “beyond a reasonable doubt.” Juries may attempt to quantify the reasonable doubt standard, even though “no such translation of the ‘reasonable doubt’ concept into mathematical terms should be attempted.”\textsuperscript{308} Thus, when the Collins court concluded that the defendant “should not have had his


\textsuperscript{300} This is the situation of the small, inbred town of 100 people. See notes 138-145 supra and accompanying text.

\textsuperscript{301} Thompson & Schumann, supra note 299, at 181-82.

\textsuperscript{302} Id. at 181. Thompson and Schumann label this tendency the “Prosecutor’s Fallacy.” They label as the “Defense Attorney’s Fallacy” the tendency to give no weight at all to evidence about matches.

The actual probability of innocence lies somewhere in between the two fallacies. It is not equal to the probability of a random match as the Prosecutor’s Fallacy would have it, but is something higher, using a formula known as the Bayes Theorem. See id. at 170 n.2.


\textsuperscript{304} 68 Cal. 2d 319, 438 P.2d 33, 66 Cal. Rptr. 497 (1968).

\textsuperscript{305} Id. at 325, 438 P.2d at 37, 66 Cal. Rptr. at 501.

\textsuperscript{306} Id.

\textsuperscript{307} Id. at 327, 438 P.2d at 39, 66 Cal. Rptr. at 503.

guilt determined by the odds,”309 the same should be true in DNA profiling cases, where similar odds are more prejudicial than probative.

Omitting the statistic completely, however, is problematic. The experts in DNA typing cases tell juries that each person has unique DNA and that they declared a match between the defendant’s DNA profile and that of the unknown sample. Without a statistical probability, juries will take this testimony to mean that the unknown sample is the defendant’s DNA. Without the statistic, then, the experts should only be allowed to declare that there is a match and to state that this does not necessarily mean that they came from the same source since no individual has a unique allele at a given locus.

Moreover, the scientific working committee proposed in Part I should thoroughly review and approve statistics concerning DNA typing before the numbers are considered so statistically insignificant that courts permit experts to dispense with the statistics and testify that a particular DNA profile is unique to the individual in question.310

Applying the relevancy balancing test then, the technique is not very probative since it is presently scientifically unreliable and unverified. Concerns of prejudice outweigh the current probative value of the technique. The prosecution’s expert witnesses oversimplify the complexities of the technique, thereby misinforming jurors. Additionally, ill-equipped cross-examiners, the tendency of jurors to be awed by the cutting-edge technology and unimpressed by the nitpicking of the defense, and the possibility of improper presentation and use of statistics increase the difficulty of a successful attack on the DNA profiling technique. Thus, on balance, DNA profiling evidence is currently more prejudicial than probative and should be excluded.

3. Assessing DNA profiling under the relevancy test:
What it looks like in Andrews.

After a brief pretrial hearing in State v. Andrews311, the trial court took the relevancy standard’s recommendation of analogies to its limits when it admitted DNA typing evidence with little more than a wave of its magic wand. The judge cited a case in which he said he was the proponent of voiceprint evidence for the State. He said that at the time of this case three of the eight jurisdictions that had considered voiceprint evidence had rejected it and there were a number of papers and articles against it as well. Yet he explained he was able to convince a

309. Collins, 68 Cal. 2d at 320, 438 P.2d at 33, 66 Cal. Rptr. at 497.
310. Courts now permit fingerprint experts to take the stand and say that each individual’s fingerprints are unique, Moss, supra note 6, at 70, without stating that the actual chance of two individuals having the same fingerprint is 1 in 64 billion. Thomas H. Maugh, Genetic Fingerprinting Joins Crime War, L.A. Times, Jan. 7, 1988, at 3, col. 1, 28, col. 2. However, part of the reason experts can do this with relative certainty is that the FBI has built up a huge database of fingerprints, making uniqueness more and more verifiable.
311. No. CR87-1400 (Orange County Cir. Ct., Fla. 1988).
Florida court to accept the evidence in the first instance and on less expert testimony than was in the case before him. The judge’s personal experience appeared to weigh heavily in favor of the admissibility of the evidence. He discussed no aspects of the experts’ testimony at the hearing. Using the standard that “[t]he admissibility of a test or experiment lies within the discretion of the trial judge,” the judge announced he would admit the DNA typing evidence. The role of the pretrial hearing appears minimal amid such a lack of meaningful analysis or of weighing the probativeness against possible prejudice.

The defendant in Andrews then appealed to the District Court of Appeal of Florida. Although the appellate court, in a footnote without further explanation, stated that the evidence would meet the Frye standard, it adopted the relevancy approach. In determining probativeness, the court simply decided that the evidence would be helpful to the jury.

In its analysis, the court used factors set out in United States v. Downing for guidance. Although different than the Williams factors, the Downing factors suffer from the same inability to determine actual scientific reliability. Applying the factors, first the court said that the DNA typing test bore a close relationship to more established modes of scientific analysis and found persuasive its extensive nonjudicial uses. However, the court also stated that a recent Florida Supreme Court case admitting protein gel electrophoresis results was noteworthy since it said this was as an important step in DNA analysis, thereby confusing the electrophoresis in DNA typing with protein gel electrophoresis, two distinct processes. As a second factor, the court said a specialized literature on the technique exists. Third, the court said the technique cannot lead to erroneous results. Outside of the Downing factors, the court also noted that the evidence had been admitted in civil cases. As this note has already discussed, not one of these factors supports the reliability of DNA typing as a forensic technique. After all, the application of the relevancy standard does not necessarily result in a determination of reliability.

313. Id. at 68-69 (citing Stevens v. State, 419 So. 2d 1058, 1063 (Fla. 1982), cert. denied, 459 U.S. 1228 (1983)).
314. Id. at 71.
316. Id. at 847 n.6.
317. Id. at 849.
318. 753 F.2d 1224 (3d Cir. 1985).
319. Andrews, 533 So. 2d at 849.
320. Id. at 846 n.4 (citing Correll v. State, 523 So. 2d 562 (Fla.), cert. denied, 109 S. Ct. 183 (1988).
321. Id. at 850.
322. Id. (The process may lead to “no results being obtained, rather than an erroneous result.”).
323. Id. n.10.
Furthermore, the court never weighed its determination of probative-ness against possible prejudice. It dispensed with the issue of the bias of the experts in a footnote stating that neither Frye nor the Florida Evidence Code requires impartiality.\textsuperscript{324} Perhaps most frustrating, however, the court recognized that the scientific evidence in this case "is highly technical, incapable of observation and requires the jury to either accept or reject the scientist's conclusion that it can be done,"\textsuperscript{325} but then did not weigh the prejudice, and found that these factors were no reason to reject the evidence.\textsuperscript{326} The court concluded that the trial court did not abuse its discretion in admitting the evidence.\textsuperscript{327}

Under the relevancy approach as applied, courts will admit DNA typing evidence with the endorsement of at least one expert, biased or unbiased. The judges will not throw out such highly technical evidence since they are unequipped to evaluate the complex processes themselves. However, the irony is that by this decision the judge has opted to leave the determination of the weight of the evidence to the jury, which is surely the least qualified to evaluate the evidence and the most likely to be swayed by it.

C. The Right to an Adequate Defense: Its Impact on the Admissibility of DNA Profiling Evidence

In addition to ensuring that scientific evidence in the courtroom is reliable, introducing DNA profiling evidence must not deny the defendant his constitutional right to an adequate defense. Although such a right is not usually urged until it is claimed by a defendant on appeal, the court still must consider it as a factor in deciding whether to admit novel scientific evidence at trial.\textsuperscript{328} This section of the note will demonstrate how two components of the right to an adequate defense—the right to expert services and the right to retest evidence—are particularly implicated by the admission of DNA typing evidence, effectively denying the defendant his right to an adequate defense in admissibility hearings.

1. The right to expert services.

The right to expert services is perhaps the most crucial component of an adequate defense in order to forestall the introduction of unreliable scientific evidence as complex and technical as DNA profiling evidence. Defense attorneys are not equipped to debate the prosecution

\textsuperscript{324} Id. at 849 n.9.
\textsuperscript{325} Id. at 850.
\textsuperscript{326} Id.
\textsuperscript{327} Id.
\textsuperscript{328} Although this section will focus on the right to an adequate defense as it affects the admission of DNA profiling evidence, the right to an adequate defense should continue to be claimed on appeal.
experts, both because they do not have the requisite knowledge and because they cannot testify before the jury.

Courts have found a right to expert services provided for by the government on several constitutional grounds. In *Ake v. Oklahoma*, the Supreme Court proclaimed a due process right to a psychiatrist when the defendant's mental condition is at issue. Many courts have interpreted *Ake* to require not simply any expert, but a defense expert; in other words, an independent, non-government expert who will help the defendant's attorney prepare the defense and interpret the findings of the prosecution's expert witness. Some courts have even determined that the expert supplied must be partisan, such that it is considered ineffective assistance of counsel when a defense attorney relies on the state expert without requesting a defense expert.

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329. There are five constitutional grounds:

1. The due process right to present a defense. See *Ake v. Oklahoma*, 470 U.S. 68 (1985) (denial of defendant's request for a court-appointed expert in psychiatry deprived defendant using insanity defense of due process). But see *Caldwell v. Mississippi*, 472 U.S. 320, 323 n.1 (1985) (rejecting the defendant's arguments that his constitutional rights were violated by the trial court's refusal to appoint fingerprint and ballistics experts since the defendant did not demonstrate that assistance was needed).

2. The right to equal protection, namely that an indigent defendant should have the basic tools for an adequate defense to place him on a similar level with the wealthier defendant. See generally *Griffin v. Illinois*, 351 U.S. 12 (1956) (plurality opinion); *Ross v. Moffitt*, 417 U.S. 600 (1974) (providing an adequate opportunity to present a defense but not to duplicate the full legal arsenal).

3. The sixth amendment right to effective assistance of counsel. It is considered ineffective assistance of counsel if defendant's counsel does not hire expert services. See Annotation, *Construction and Application of Provision in Subsection (e) of Criminal Justice Act of 1964 (18 U.S.C. Sec. 3006A(e)) Concerning Right of Indigent Defendant to Aid in Obtaining Services of Investigator or Expert*, 6 A.L.R. Fed. 1007 (1971) (citing *Proffitt v. United States*, 582 F.2d 854 (4th Cir. 1978); *United States v. Fessel*, 531 F.2d 1275 (5th Cir. 1976); *Loe v. United States*, 545 F. Supp. 662 (E.D.Va. 1982)). It is then but a short step to a sixth amendment duty imposed upon the state to provide expert assistance for the indigent defendant. P. GIANNELLI & E. IMWINKELRIED, supra note 15, at 137-38.

4. The sixth amendment right to compulsory process, including the defendant's right to obtain witnesses in his favor. See *People v. Watson*, 36 Ill. 2d 228, 221 N.E.2d 645 (1966).


331. See, e.g., United States v. Crews, 781 F.2d 826, 834 (10th Cir. 1986); United States v. Sloan, 776 F.2d 926, 929 (10th Cir. 1985); Barnard v. Henderson, 514 F.2d 744 (5th Cir. 1975); Marshall v. United States, 425 F.2d 1315 (10th Cir. 1970) (plain error for trial court to appoint the FBI as defense investigator); Holloway v. State, 257 Ga. 620, 561 S.E.2d 794 (1987). The Tenth Circuit in *Marshall* said, "Just as an indigent defendant has a right to appointed counsel to serve him as a loyal advocate, he has a similar right under properly proven circumstances to investigative aid that will serve him unfettered by an inescapable conflict of interest." 423 F.2d at 1319.

However, the courts do not consider all denials of defense requests for expert services to be constitutional violations. There are at least four circumstances under which courts have denied expert services: 1) where the expert’s information would not be pivotal; 2) where an "impartial" government expert would suffice; 3) where cross-examination of the prosecution’s expert was effective; and 4) where the expert’s testimony would not change the verdict.\(^3\)

None of these circumstances applies to the admission of DNA profiling evidence. First, the evidence is almost always pivotal since it usually goes directly to the issue of the guilt or innocence of the defendant.

Second, the only way to show a lack of consensus or a lack of general acceptance in the scientific community is to have a defense expert testify to this effect. This is where an admissibility hearing on novel scientific evidence deviates from the situation where a technique has already been accepted as reliable and thus there is such a person as an "impartial" government witness who is simply interpreting the results of a widely-accepted test. In an admissibility hearing, the scientific community is being asked its opinion on the reliability of the evidence and the defense must have the opportunity to answer the question in the negative. This is impossible without a defense expert.

Third, cross-examination is rarely going to be effective with a complex, technical technique such as DNA profiling. A defense attorney who did not hire a defense expert—for advice, at the very least—would be ineffective.

Finally, if the defense could show that it would have a defense expert testify to a lack of scientific consensus on the reliability of the forensic technique, this could change the outcome of a hearing without defense experts, and the court should not deny, in advance, a request for expert services. On these four grounds, a court must grant a request for expert services in a DNA profiling admissibility hearing or the defendant will be deprived of his right to an adequate defense.

However, the right to expert services is meaningless if the defendant’s request is granted but he is effectively prevented from fulfilling it. There are two traditional reasons not specific to DNA profiling evidence why this may happen. One reason is plain omission by the de-

\(^3\) See, e.g., United States v. Perrera, 842 F.2d 73 (4th Cir. 1988) (defendant was not prejudiced by refusal to appoint handwriting expert to assist in responding to government's expert who merely corroborated other evidence that the defendant had signed the documents in an insurance fraud scheme); United States v. Brewer, 785 F.2d 841 (9th Cir. 1986) (burden of showing actual prejudice by clear and convincing evidence not met if cross examination of eyewitness seemed effective without the assistance of an expert); United States v. Sanders, 459 F.2d 1001 (9th Cir. 1972) (trial court did not err in refusing defense request for expert medical witness since offer of proof showed that expert's testimony would not have changed the outcome); United States v. Jones, 320 F. Supp. 901 (E.D. Tenn. 1971) (post-conviction defense motion denied where defendant sought fingerprint expert to examine the evidence of the prosecution's expert, who was effectively cross-examined); Decker, supra note 329, at 591-92, 597.
fense attorney, which unfortunately can only be attacked on appeal as ineffective assistance of counsel. A second reason is a lack of resources for the indigent defendant. Although about half the states and the federal government have statutes which provide funds for defense experts, those funds are prohibitively low, and the statutes suffer from the problematic interpretations of what is considered “necessary” to a defense. Economic status is very often an effective bar to an adequate defense.

However, there is a third reason, which is unique to admissibility hearings for novel scientific evidence, why a defendant in a DNA profiling admissibility hearing is effectively prevented from fulfilling his right to expert services. Assuming the possibility that the technique has not yet been adequately reviewed by the relevant scientific community, there may not be an expert in the field intimately acquainted with the forensic technique other than the biased proponents of the technique. The defense attorney cannot be expected and is not equipped to begin the process of scientific inquiry in order to generate possible opposition to the technique and hence a pool of potential defense experts.

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334. See note 329 supra (sixth amendment right to effective assistance of counsel).
335. For a list of those statutes, see A. Moenssens, F. Inbau & J. Starrs, supra note 15, at 14 n.41.
337. Some courts do not give compensation equal to what the government pays its witnesses, but rather, what is a fair and reasonable charge in the locality in which the services were rendered. See United States v. Pope, 251 F. Supp. 234, 241 (D. Neb. 1966).
338. Thus, rarely will the indigent defendant be placed on a level anywhere near the nonindigent defendant, except perhaps when a concerned scientist such as Dr. Eric Lander offers to testify for free, as he did in Castro. Lander’s Castro Report, supra note 53, at 1.
339. For instance, courts do not allow expenditure of the funds under the Federal Criminal Justice Act for “mere fishing expeditions,” a subjective determination which could mean the indigent defendant is prevented financially from exploring a full defense. See United States v. Kasto, 584 F.2d 268, 273 (8th Cir. 1978) (trial court’s denial of defendant’s request for investigator services to investigate rape victim’s reputation in the community not abuse of discretion since it was a “mere fishing expedition” and the defense did not show why the two court-appointed lawyers could not do the investigating); but see United States v. Schultz, 431 F.2d 907, 911 (8th Cir. 1970) (although an expenditure under the statute should not be authorized for a “mere fishing expedition,” the expenditure should be provided if further investigation may prove beneficial).
340. Some courts, however, construed the language of the federal statute, allowing for services “necessary to an adequate defense,” as broadly as possible to include preparation of the cross-examination of the prosecution’s expert. See United States v. Durante, 545 F.2d 825 (2d Cir. 1976); see also United States v. Patterson, 724 F.2d 1128 (5th Cir. 1984) (if the government’s case depends heavily upon expert testimony, then the indigent defendant must be given the opportunity to prepare and present the case with its own expert). The test used by many courts is whether a “reasonable attorney” would employ such services for a client with the financial means to pay for them. See United States v. Hartfield, 513 F.2d 254, 258 (9th Cir. 1975); Brinkley v. United States, 498 F.2d 505, 510 (8th Cir. 1974).
341. “There can be no equal justice where the kind of trial a man gets depends on the amount of money he has.” Griffin v. Illinois, 351 U.S. 17, 19 (1956) (Black, J.).
admit novel scientific evidence before the unbiased members of the scientific community have had contact with the forensic technique is to deny the defendant an opportunity to explain ways in which the technique is unreliable. The only way to ensure that the reason a defendant does not have a defense expert in such hearings is because of scientific consensus on reliability is to have the scientific community pass on the technique before it appears in the courtroom.

2. The right to retest.

The admission of DNA typing evidence also has an impact on the right to have an expert retest the prosecution’s evidence. Some courts have found such a right as part of the defendant’s right to an adequate defense.339

This right to retest may be conditioned on a preliminary showing that the results will be favorable to the defendant,340 or on a showing that the evidence is critical and “subject to varying expert opinion.”341 When determining the admissibility of novel scientific evidence such as DNA profiling evidence, the reliability of the procedure is as yet unproven and thus is subject to varying expert opinion. Furthermore, because of the unproven reliability, one cannot state with certainty what the results of a retest would be, whether favorable or unfavorable.

Some courts reject the notion that the right to retest is a due process right since the opportunity to cross-examine the prosecution’s expert witness should be sufficient.342 Professors Paul Giannelli and Edward Imwinkelried do not find this rationale persuasive:

First, there is a significant difference between attacking the opinion of an opponent’s expert through cross-examination and attacking that opinion through the testimony of a defense expert. Second, the results of [laboratory proficiency testing programs] demonstrate the fallibility

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339. See Barnard v. Henderson, 514 F.2d 744, 746 (5th Cir. 1975) (“Fundamental fairness is violated when a criminal defendant . . . is denied the opportunity to have an expert of his choosing, bound by appropriate safeguards imposed by the Court, examine a piece of critical evidence whose nature is subject to varying expert opinion.”); United States v. Stifel, 433 F.2d 431, 441 (6th Cir. 1970) (if the government is going to use expensive, time-consuming methods of factfinding, it must allow time for the defendant to make a similar test and the means for an indigent defendant to do so), cert. denied, 401 U.S. 994 (1971).

In addition to the constitutional right, courts also recognize the right to retest as part of defense discovery. Most jurisdictions have discovery rules that allow for disclosure of the prosecution’s scientific reports to the defense, and many provide for defense inspection of documents and tangible objects, such as bullets, footprint impressions, articles of clothing, and materials found at the scene. Some interpret and extend the provision for inspection to include retesting. See Fed. R. Crim. P. 16 (broadly defining what can be discovered and inspected); P. GIANNELLI & E. IMWINKELRIED, supra note 15, at 87, 93, 95-96.


341. Barnard, 514 F.2d at 746.

of crime laboratory analysis and thus the need for retesting.\textsuperscript{343}

Certainly cross-examination is insufficient in DNA profiling cases to uncover often undetected mistakes in the testing procedure which can lead to false matches.

Where the right to retest is recognized, the prosecution has an obligation to give notice of its intention to use the evidence so that the defense has an adequate opportunity to examine it.\textsuperscript{344} Furthermore, if the prosecution’s testing will consume the entire sample, as is often the case in DNA profiling, the prosecution is required in several states to contact the defense attorneys so that they can have their own expert present.\textsuperscript{345} Most courts have held, however, that it is not a constitutional violation if the expert consumes the evidence in a necessary test.\textsuperscript{346}

The right to retest the sample is crucial to the issue of admissibility of DNA typing evidence and the adequacy of the defense. Even if the defense is able to find an expert to testify, that expert will find it difficult if not impossible to locate errors in the particular test as performed if she is not present when the testing is done. For example, if the probes used in the test were contaminated and created a false positive, the defense expert will only be able to surmise that this may have happened.

The reliability of a technique means that the test results can be reproduced; thus, it is imperative that members of the scientific community retest, or at least view, the procedure. When a technique is novel, this process must occur first out in the scientific community, and not in the courtroom, in order to establish general reliability.

Thus, the constitutional right to an adequate defense is another reason why the courtroom is the improper forum for the determination of the reliability of new forensic techniques. Only after the scientific community has reviewed the technique can defense attorneys put forth an adequate defense. It is then that they will know what kind of a defense exists for attacking the admissibility of the evidence. In the meantime,

\begin{itemize}
  \item \textsuperscript{343} Id. at 97-98.
  \item \textsuperscript{344} See United States v. Kelly, 420 F.2d 26 (2d Cir. 1969) (results of neutron activation analysis not admissible because defense was not informed of it until trial, and therefore had no opportunity to make similar tests and seek its own expert).
  \item \textsuperscript{345} See P. Giannelli & E. Imwinkelried, supra note 15, at 98 nn.53-56 (citing People v. Gomez, 198 Colo. 105, 112, 596 P.2d 1192, 1197 (1979), \textit{cert. denied}, 455 U.S. 943 (1982); State v. Gaddis, 530 S.W.2d 64, 69 (Tenn. 1975); State v. Wright, 87 Wash. 2d 783, 793, 557 P.2d 1, 7 (1976); \textbf{COLO. REV. STAT.} \textsect 16-3-309 (1984) (outlines factors court should consider when deciding whether to admit the results of a test which consumed all but an unusable amount of the sample); \textbf{MONT. CODE ANN.} \textsect 46-15-302(3)(a) (1981); \textbf{OHIO REV. CODE ANN.} \textsect 2925.51(E) (Baldwin 1983)).
  \item \textsuperscript{346} See id. at 109 n.98. If the test is unnecessary, however, consumption of the evidence may be a constitutional violation. \textit{See} People v. Gomez, 198 Colo. 105, 596 P.2d 1192 (1979) (consumption of heroin in unnecessary test violates due process), \textit{cert. denied}, 455 U.S. 943 (1982).
\end{itemize}
the admission of DNA profiling evidence into the courtroom denies the criminal defendant his right to an adequate defense.

D. Proposal for Admission of Novel Scientific Evidence

Most judges and juries are not equipped to evaluate sophisticated technology such as DNA profiling. Cases thus far illustrate that both judges and juries can be too impressed with the opportunity to dabble in the cutting-edge techniques of genetics to realize that there may be much more to the technique than that which comes from the mouths of select expert witnesses. The scientific dispute over the reliability of the technique is playing itself out in the adversarial environment of the courtroom, where rules of evidence, stilted formalism, leading questions, and protections of proprietary information hinder open scientific inquiry. The scientific community should not be forced to debate the reliability of scientific techniques in the courts.

Neither the Frye standard nor the relevancy standard is acceptable for admitting evidence such as DNA profiling against a defendant in a criminal trial. Courts do not follow the true intentions of Frye; they will either manipulate the standard to admit evidence that the scientific community has not truly evaluated or will receive information from a few experts in a trial setting that is simply inadequate to make a proper determination as to general acceptance. Worse yet, as soon as an appellate court upholds a trial court’s determination on these inadequate grounds, there will no longer be Frye hearings in that jurisdiction and the evidence will go directly to the jury. The relevancy standard immediately gives the same determinations to the jury, who will not second-guess an expert’s determination of a match.

The proposal here is closely linked to the proposal in Part I. A working committee, including scientists, forensics experts, and lawyers should designate certain categories of novel scientific evidence that may be too complex for evaluation by laypersons. When forensic scientists consider a new technique that falls into one of the categories, the committee should make recommendations to Congress as to whether the procedure is too complex for evaluation of its reliability by a judge or jury. If so, a scientific working committee will proceed to evaluate the technique as proposed in Part I.

In deciding whether the technique is reliable, the standard for scientific reliability should be at least the standard of proof the prosecution must meet in order to convict a defendant. In other words, the tech-

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347. When a California superior court judge ruled that DNA typing evidence passed the Frye test, Rockne Harman, the prosecutor in the case, said, “It’s reinforcing that judges haven’t been confounded by all of this technical stuff... Hopefully we won’t have to spend too much more of the taxpayer’s money in these legal hearings before we can use such evidence routinely.” David Oltman, Judge Allows DNA Tests in Alameda, Daily J., Sept. 25, 1989, at 10. Judges and prosecutors have ignored the significance of “the technical stuff” in their excitement to see the evidence admitted.
nique should be considered reliable beyond a reasonable doubt.\textsuperscript{348} If it is found to be unreliable, the committee will design further research and validation studies and set standards. Once it is found reliable, Congress should implement legislation for the admission of the evidence in a uniform manner on a national level. Only after this process takes place should a defendant's freedom be placed in jeopardy on the basis of DNA typing evidence.\textsuperscript{349}

The above proposal does not apply when it is the defendant who seeks to introduce the DNA typing evidence. A lower standard of admissibility for the evidence when the defendant is the proponent is both scientifically and legally justifiable. From a scientific standpoint, as the court decided in \textit{Castro}, and as all the experts in that case agreed, allowing evidence of an exclusion—that the two prints do not match—does not involve the controversial areas of declaring matches and stating probability statistics, and it is much easier and more reliable for a scientist to declare a nonmatch than a match.\textsuperscript{350} From a legal standpoint, criminal defendants have a constitutional right to present defense evidence.\textsuperscript{351} The criminal defendant and civil litigant should need only to establish the validity of a technique by a preponderance of the evidence.\textsuperscript{352}

However, since most scientific evidence in the courtroom is introduced by the prosecutor and not the defendant, the major concern of this note is that judges and juries tend to give the admission of scientific evidence precedence over the rights of defendants who have few resources to dispute its reliability.

III. OUT OF THE COURTROOM AND INTO THE COMMUNITY: PRIVACY CONCERNS

\textit{Power is in tearing human minds to pieces and putting them together again in new shapes of your own choosing. . . . We have cut the links between child and parent, and between man and man, and between man and woman. No one dares trust a wife or a child or a friend any longer. But in the future there will be no wives and friends. Children will be taken from their mothers at birth, as one takes eggs from a hen. The sex instinct will be eradicated. Procreation will be an annual formality like the renewal of a ration card. We shall abolish the orgasm. Our neurologists}

\begin{footnotesize}
\textsuperscript{348} This is the suggestion of at least two commentators on forensic evidence. See Giannelli, \textit{supra} note 177, at 1248; G.T.C. Lambourne, \textit{Fingerprint Standards}, 24 MED. SCI. L. 227, 229 (1984) ("I feel that at all times our conception of our identification standard must equal our conception of justice. In other words, I believe that fingerprint evidence must be of the highest quality possible, and it is my conviction that it is neither desirable, nor necessary, to reduce these standards.").

\textsuperscript{349} In the interim, the hundreds of defendants who were convicted with the help of unreliable evidence deserve retrials. The National Association of Criminal Defense Lawyers has formed a committee in response to \textit{Castro} to reopen cases in which convictions were based on DNA evidence. Sherman, \textit{supra} note 44, at 14.

\textsuperscript{350} \textit{Castro Admissibility Decision}, \textit{supra} note 62, at 27; see note 64 \textit{supra}.


\textsuperscript{352} See Giannelli, \textit{supra} note 177, at 1248.
\end{footnotesize}
are at work upon it now... If you want a picture of the future, imagine a boot stamping on a human face—forever.353

The potential probative value of DNA profiling evidence makes it especially vulnerable to two forms of abuse.354 First, because a tissue sample from a person detained by the police may offer nearly positive identification through DNA typing, courts may be tempted to stretch the exceptions to the fourth amendment’s requirement that a warrant based on probable cause precede a search. However, because of the wide-ranging amount of information about a person that a DNA typing test may generate, the fourth amendment should protect persons to a greater, not a lesser, extent in this context.

The second form of abuse has the potential to affect the entire population. A databank of DNA profiles could eventually offer information that could be used in a discriminatory manner to deprive individuals of benefits and services. As this note will argue, it is not mere paranoia to imagine the incremental steps the current government would take that would lead from a databank with DNA profiles on criminals to a databank with DNA profiles on each of us.

The following subsections explicitly address these two forms of abuse and urge that the need to protect against the invasion of privacy, including that of criminal suspects, prisoners, and the community at large, is real and immediate.

A. Marshalling the Fourth Amendment to Protect the Rights of Criminal Suspects

Before the police arrested Tommie Lee Andrews and ordered a DNA typing test performed linking him to two different rapes, they were stumped.355 Police had been looking for the perpetrator of a number of rapes in the area, but they encountered difficulty identifying suspects since the rapist had covered each of the victims’ faces.356 Inadequate identification of the perpetrator by victims and witnesses is an issue constantly plaguing law enforcement officials.

What if one of the rape victims had told the police that she saw blue pants before her face was covered, and police apprehended a suspicious man in blue pants lurking around the victim’s building immediately after the rape? Even if this suspicion could amount to the “specific and articulable facts”357 which might allow the police to de-

353. G. ORWELL, supra note 2, at 220.
354. This section assumes either that the scientific community will do further research, implement certain controls, and eventually decide that the technique is reliable enough for forensic use such that it is accepted in the courts, or that, despite the urging of this note, the evidence is going to continue to be admitted in its current form. Either way, the possibility that it may be introduced on a large scale must be considered.
355. Tommie Lee Andrews was the defendant in Andrews v. State, 533 So. 2d 841 (Fla. Dist. Ct. App. 1988), discussed at notes 311-327 supra and accompanying text.
356. See Lewis, supra note 58, at 46.
tain this man, there may be little evidence police could recover which would be probative enough to tempt them to conduct an extended and perhaps unlawful search. However, the potential of DNA typing changes the stakes. The desire to obtain evidence from this man increases when the possibility exists that a tissue sample taken from the suspect could positively identify the man as the perpetrator. Yet, however probative this evidence and however great society's interest in apprehending the perpetrator of numerous rapes, the extraction of evidence for DNA profiling without a warrant based on probable cause violates an individual's "reasonable expectation of privacy." 358

The Supreme Court has already confronted a temptation to broaden one of the "few specifically established and well-delineated exceptions"359 to the fourth amendment's requirements in the area of fingerprinting. This exception is the "investigatory detention," which the courts derived from the "stop and frisk" exception created in Terry v. Ohio. 360 The investigatory detention allows the police to detain a person, question him, and frisk him on less than probable cause. 361 Although the Supreme Court has not yet decided the constitutionality of conducting compulsory identification procedures during such a detention, it has indicated in two separate decisions that it may be possible to detain a person briefly in the field for fingerprinting.

In Davis v. Mississippi, 362 although the Court held that detention solely for the purpose of fingerprinting is protected by the fourth amendment and thus requires a warrant, it stated in dictum that

because of the unique nature of the fingerprinting process, such detentions might, under narrowly defined circumstances, be found to comply with the Fourth Amendment even though there is no probable cause in the traditional sense.... Detention for fingerprinting may constitute a much less serious intrusion upon personal security than other types of police searches and detentions. 363

The Court suggested a balancing approach, weighing the police need for the evidence against the severity of the personal intrusion. 364

The Court took this idea a step further in Hayes v. Florida. 365 The Court held that, without a warrant or probable cause, the police cannot forcibly take a person from his home and transport him to the police station for fingerprinting since that would be tantamount to an

359. Id. at 357.
363. Id. at 727.
364. Id. at 727-28.
arrest. However, the Court added, that does not imply "that a brief detention in the field for the purpose of fingerprinting, where there is only reasonable suspicion not amounting to probable cause, is necessarily impermissible under the Fourth Amendment." The Court further suggested that it may be constitutional to seize a person on less than probable cause and remove him to the police station for fingerprinting under circumscribed procedures. However, the protections of the fourth amendment will be triggered if the police activity becomes too intrusive or the stop takes too long.

Although the Court did not hold that compulsory identification procedures could occur on less than probable cause, a number of jurisdictions passed statutes or adopted court rules in the wake of the Davis dictum allowing exactly that. Not only do these jurisdictions allow detention for identification procedures on less than probable cause, but they allow it for procedures far more intrusive than fingerprinting.

Such rules and statutes go far afield of the limited "frisk" on less than probable cause sanctioned by Terry—namely, one "reasonably related in scope to the circumstances which justified the interference in the first place." As the Court explained in Florida v. Royer, "the investigative methods employed should be the least intrusive means reasonably available to verify or dispel the officer's suspicion in a short period of time." As Terry noted, "[e]ven a limited search of the outer clothing for weapons constitutes a severe, though brief, intrusion upon cherished personal security, and it must surely be an annoying, frightening, and perhaps humiliating experience." Compulsory identification procedures which probe beneath the body's surface, such

366. Id. at 815-16.
371. Four states require reasonable grounds to suspect that a person committed an offense, two states only require a showing that the evidence might contribute to the identification of the perpetrator, and one state requires probable cause that the perpetrator is one person of a small group. See Asselta, supra note 370, at 508.
375. Id. at 500.
376. Terry, 392 U.S. at 24-25.
as the taking of blood, go directly against the Court’s mandate that such procedures are unconstitutional on less than probable cause without exigent circumstances and a clear indication that the evidence will be found.\textsuperscript{377} Courts in jurisdictions that do not have such rules or legislation explicitly require probable cause for nontestimonial compulsory identification procedures.\textsuperscript{378}

However, the temptation of the Court to make exceptions for fingerprinting still remains. Although fingerprinting would not appear to be a search confined to the limits dictated by \textit{Terry}, the Court considered fingerprinting to be a unique process. The concern of this note is that the Court would find its reasons for justifying an exception for fingerprinting applicable to DNA profiling.

There are at least four reasons the Court may be willing to make an exception for fingerprinting, and hence DNA “fingerprinting” as well. First, fingerprint expert claims that each person’s fingerprint is unique. Therefore the probative value of the evidence is high. DNA typing experts are of the same making a similar claim of specificity. Second, the fingerprint is likely to lead to the evidence sought, and hence is not a search based on “the mere chance that desired evidence might be obtained.”\textsuperscript{379} The DNA profile has an even greater chance than the fingerprint of identifying a suspect: There are more innocent explanations for leaving fingerprints at the scene of the crime than for leaving blood or semen. Third, fingerprinting is a relatively nonintrusive procedure.\textsuperscript{380} Although DNA typing is still most often performed on the fresh blood samples of suspects, a notably intrusive procedure, testing may eventually be performed on a few hairs or saliva, involving much less intrusive procedures.\textsuperscript{381} Finally, fingerprints are physical


\textsuperscript{379} Schmerber, 384 U.S. at 769-70.

\textsuperscript{380} In \textit{Davis v. Mississippi}, Justice Brennan stated this as one of the reasons why fingerprinting was of a “unique nature.” 394 U.S. 721, 727 (1969). The other reasons that he stated were: Repeated fingerprinting or harassment is not a real danger since the police need only one set of prints; fingerprinting is very reliable as compared with confessions or eyewitness testimony; and, since there is no danger of destruction of the evidence, fingerprinting can be done at convenient times. \textit{Id.} at 727. As Professor LaFave explains, these reasons equally support many other forms of identification evidence, and hence are not persuasive to create a special exception for fingerprinting. 3 W. LaFAVE, supra note 361, § 9.6(b), at 571-75.

\textsuperscript{381} The taking of urine samples, saliva samples, and hair clippings have been upheld as valid warrantless searches incident to arrest since the procedures involved do not probe beneath the surface of the skin. \textit{See} 1 Joseph Cook, \textit{Constitutional Rights of the Accused} § 3:20, at 467-70 (2d ed. 1985); 2 W. LaFAVE, supra note 361, § 5.3(e), at 499. However, it is important to note that currently the DNA from the hair root must be obtained in order to run
characteristics displayed to the public, thus involving fewer privacy concerns than blood samples.\textsuperscript{382} As the Supreme Court said in \textit{Davis}, "Fingerprinting involves none of the probing into an individual's private life and thoughts that marks an interrogation or search."\textsuperscript{383} At first glance, some physical evidence that could be used for DNA profiling, such as hair, would seem to be displayed to the public. However, the evidence sought is not the hair but the DNA, and this is the crux of the difference between fingerprinting, and indeed many other types of compulsory identification procedures, and DNA profiling.

The information obtained by DNA profiling, whether it comes from blood, saliva, semen, or hair, is potentially quite extensive and personal. Obtaining a DNA profile may eventually be more invasive of an individual's privacy than rifling through personal files. Scientists have already located the sites of many genetic diseases and disorders; it is only a matter of time before the entire human genome is mapped.\textsuperscript{384} Although current procedures only identify the lengths of various DNA fragments, DNA base sequencing would give an individual's genetic code.\textsuperscript{385} Although only intending to seize evidence that would identify the suspect as the perpetrator of the crime, police would in fact be seizing the medical, physiological, racial, ethnic, and genealogical history of the suspect as well.

This unique informational aspect of DNA profiling adds a new dimension to the entire fourth amendment analysis of what is a reasonable search in the context of compulsory identification procedures on less than probable cause. The balancing test for the "reasonableness" of such procedures involves weighing the need of the police for the evidence against the invasion of individual privacy.\textsuperscript{386} With compulsory identification procedures, courts have traditionally thought of the level of bodily intrusion as the measure of the invasion of privacy. Thus, intrusion beneath the body surface invades bodily integrity so that the search is generally not reasonable without a warrant.\textsuperscript{387}

\textsuperscript{382} Features that one exhibits to the public may not be protected by the fourth amendment since one does not have a legitimate expectation of privacy in them. Thus, handwriting samples and voice recordings do not implicate the fourth amendment. United States v. Mara, 410 U.S. 19 (1973) (handwriting); United States v. Dionisio, 410 U.S. 1, 5 (1973) (voice recording).


\textsuperscript{384} See note 23 supra.

\textsuperscript{385} See text accompanying notes 51-52 supra.

\textsuperscript{386} \textit{See Davis}, 394 U.S. at 721; \textit{see also O'Connor v. Ortega}, 480 U.S. 709, 719-20 (1987).

\textsuperscript{387} This unique informational aspect of DNA profiling adds a new dimension to the entire fourth amendment analysis of what is a reasonable search in the context of compulsory identification procedures on less than probable cause. The balancing test for the "reasonableness" of such procedures involves weighing the need of the police for the evidence against the invasion of individual privacy. With compulsory identification procedures, courts have traditionally thought of the level of bodily intrusion as the measure of the invasion of privacy. Thus, intrusion beneath the body surface invades bodily integrity so that the search is generally not reasonable without a warrant.
However, the sort of privacy invasion implicated by gaining access to DNA profiling information goes beyond simply physical invasion and thus deserves heightened protection. In United States v. Jacobsen, the Supreme Court indicated that onsite testing on less than probable cause which would reveal private information would be impermissible. In Jacobsen, the Court upheld the warrantless field-testing of a powder, but only because “[a] chemical test that merely discloses whether or not a particular substance is cocaine does not compromise any legitimate interest in privacy.” The Court may have decided differently if the test had revealed the identity of the drug. The dissent expressed concern, however, that the focus was on what was being searched instead of how it was being searched. This note urges that both must be focused upon in the context of DNA profiling. Not only should the traditional protections of bodily integrity apply, but protections against the seizure of private information unrelated to criminal activity should also apply. Since in a DNA typing test a hair can reveal the same physiological secrets as a drop of blood, it would make little sense to draw lines only at the level of physical intrusion.

The impact of these considerations of privacy in DNA profiling are twofold. First, given the extreme level of intrusiveness in the gathering of such personal information, the technique should not be included in any extensions of the investigatory detention exception to fingerprinting or other relatively nonintrusive identification procedures.

Second, even if police obtain the evidence for DNA profiling with a warrant, procedures must be designed to ensure that unrelated personal information obtained from the DNA profile is not used without consent or made a part of a police record. Once a DNA profile is legitimately seized from a person, the fourth amendment does not protect the uses to which it is put. Therefore, a prosecutor could potentially place various genetic characteristics before the jury. Although it is uncertain at this point what sort of information might be included in


On the other hand, urine samples, saliva samples, hair clippings, breath samples, x-rays, and the placing of the suspect’s hands under an ultraviolet light are upheld as reasonable searches incident to arrest since they do not probe beneath the body’s surface. See note 381 supra.

389. Id. at 123.
390. Id. at 139-40 (Brennan, J., dissenting).
391. In In re Fingerprinting of M.B., 125 N.J. Super. 115, 309 A.2d 3 (1973), the appellate court, in upholding an order that 22 students appear for fingerprinting in connection with the investigation of a homicide, found it significant that the trial court ordered that the prints be destroyed upon completion of the investigation. See 3 W. LAFAVE, supra note 361, § 9.6(b), at 578 (discussing the case in connection with the need for special procedures to minimize the impact of identification procedures on less than probable cause).
a person's DNA that would be admissible at trial, it is important to consider the magnitude of the invasion of privacy. It is impossible to prevent the police from gathering the extraneous information, since a seizure of DNA is by its very nature overbroad. On policy grounds, however, the results of the DNA typing test which are admitted at trial should be limited to the ultimate issue of guilt or innocence in the case.

Furthermore, since DNA may reveal private information such as legitimacy at birth and genetically inherited diseases, it appears to have more qualities of forced testimonial evidence than simple physical evidence. The Supreme Court has determined that the fifth amendment's protection against self-incrimination extends only to testimonial evidence, which does not include hair, blood, or semen. However, given the unique autobiographical nature of the evidence that DNA fingerprinting reveals, the Court should reconsider its strained categories of testimonial and nontestimonial evidence; DNA typing evidence fits into both categories.

An even larger concern than impermissible uses of the DNA profile at trial, however, is that impermissible uses of stored DNA could occur elsewhere in the community. A databank of DNA profiles, as discussed in the next section, creates much broader threats for intrusions of individual privacy.

B. The DNA Profile Database and Its Threat to the Privacy and Security of the Individual

Imagine a society where the government had samples of tissue and fluid from the entire community on file and a computerized databank of each individual’s DNA profile. Imagine then that not only law enforcement officials, but insurance companies, employers, schools, adoption agencies, and many other organizations could gain access to those files on a “need to know” basis or on a showing that access is “in the public interest.” Imagine then that an individual could be turned down for jobs, insurance, adoption, health care, and other social services and

392. Although originally the Court saw forcible extraction of evidence from the body as similar to coerced confessions, see, e.g., Rochin v. California, 342 U.S. 165 (1952) (pumping of defendant’s stomach for drugs was prohibited as a form of self-incrimination), the Court retreated from this analogy, see Breithaupt v. Abram, 352 U.S. 432 (1957) (using only the fourth amendment search and seizure protections to hold that a blood test taken from an unconscious suspected drunk driver was reasonable). Finally, in Schmerber v. California, 384 U.S. 757 (1966), the Court rejected entirely the notion that the fifth amendment applied to “nontestimonial” evidence, and therefore the withdrawal of blood did not implicate the privilege against self-incrimination. In general, all physical evidence is nontestimonial. No court has held that the type of evidence used for DNA typing—e.g., blood, hair, semen—is testimonial or violates the privilege against self-incrimination.

393. However, some courts have already considered certain combinations of testimonial and physical evidence and denied the protection of the fifth amendment. See, e.g., State v. Mitchell, 755 S.W.2d 603 (Mo. App. 1988) (defendant’s privilege against self-incrimination not violated when required in the presence of the jury to utter words used by the perpetrator of the robbery for voice identification); Cranberry v. State, 745 S.W.2d 34 (Tex. App. 1987) (soundless videotape is not testimonial for purposes of the fifth amendment).
benefits on the basis of information contained in her DNA profile, such as genetic disease, heritage, or someone else’s subjective idea of a genetic “flaw.”

“Genetic redlining”—the experience of differentiated treatment based on apparent or perceived human variation,—is not a figment of the imagination. Examples of it scar the history of this nation. The eugenics movement of the 1920s, which called for the compulsory sterilization of social undesirables, or those “dependent on the State,” was endorsed by some of our nation’s most “enlightened” citizens. In upholding a Virginia law compelling sterilization of those judged to be “the probable potential parent of socially inadequate offspring likewise afflicted,” Justice Oliver Wendell Holmes stated:

We have seen more than once that the public welfare may call upon the best citizens for their lives. It would be strange if it could not call upon those who already sap the strength of the state for these lesser sacrifices, often not felt to be such by those concerned, in order to prevent our being swamped with incompetence.

The eugenics movement was not a passing fad. By 1956, 58,000 people had been sterilized under these laws. In 1966, at least twenty-three states still had not repealed their sterilization laws and at least ten states still provided for sterilization of epileptics and criminals.

Genetic screening legislation has also been popular in the recent past. For instance, beginning in the early 1970s, states passed laws to identify the carriers of the sickle cell anemia gene, ostensibly to warn people about the risks of bearing children with the disease. The premarital screening was a form of negative eugenics to discourage people from marrying carriers of the disease. Some laws mandated screening preschool children as well, which was socially stigmatizing and disruptive of family units, since sensitive questions of paternity were raised when the testing revealed that neither legal parent had the trait. Furthermore, because blacks are the primary carriers of the gene, “genetic discrimination” quickly turned into racial discrimination when unfounded fears of the disease led to decreased employment op-

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394. FBI DNA Fingerprinting Hearing, supra note 24, at 9 (statement of Philip Bereano, Professor of Engineering & Public Policy, University of Washington) (on file with the Stanford Law Review) [hereinafter Bereano Testimony].
396. Id. at 125.
399. Id. at 128.
400. See generally id. at 37-148 (discussing three waves of genetic screening legislation: testing of infants for phenylketonuria (“PKU”) to prevent mental retardation; identification of persons with the gene for sickle cell anemia; and current expansion of PKU testing of infants for other genetic disorders).
401. Id. at 67.
402. Id. at 69-71.
portunities as well as higher insurance premiums for blacks.403

Today, the potential of DNA profiling offers even more opportunity for invasion of privacy and "genetic redlining." The current effort by the FBI and several states to create DNA profiling databanks of criminals is the first dangerous step.404 However, few people are thinking this far ahead. John Hicks, Deputy Assistant Director of the FBI, claimed that the computer databank would be "nothing more than an information management and screening tool."405 This is, however, a broad definition which has some rather ominous implications for the future.

Jurisdictions building databanks currently contemplate filing only the profiles of paroled felons.406 However, as Professor Philip Bereano related to Congress in the March 1989 hearings on DNA profiling, when the fingerprinting system was established as a law enforcement tool, no one contemplated that he would be required at age 12 to be fingerprinted for his job delivering newspapers.407 In the case of DNA typing, Lifecodes is already planning to bank DNA information on newborns for parents who want to be able to trace and identify their children in case of kidnapping or runaways.408 In addition, immigration authorities have expressed an interest in participating in a DNA databank for their purposes.409

In its testing zeal, the current government is already well on its way to accumulating fluid and tissue samples on many members of mainstream society. Mandatory drug testing410 and AIDS testing411 could

403. Id. at 74.
404. In March 1988, King County, Washington passed an ordinance requiring DNA testing of all convicted sex offenders. Beeler & Wiebe, supra note 23, at 924 n.116 (citing King County, Wash. Ordinance 8453 (Mar. 28, 1988)). However, the collection of samples was on hold as of March 1989, pending the results of an assessment of actual benefits, i.e., the number of convictions that would actually be obtained by the use of a database, to see if the intrusions on privacy would be justifiable. See Bereano Testimony, supra note 394, at 2.
405. FBI DNA Fingerprinting Hearing, supra note 24, at 9 (statement of John Hicks, Deputy Assistant Director, Laboratory Division, FBI) (on file with the Stanford Law Review) [hereinafter Hicks Testimony].
406. See note 404 supra.
408. Unger, supra note 29, at 47.
409. See id.
410. See, e.g., Skinner v. Railway Labor Executives Ass'n, 109 S. Ct. 1402 (1989) (uphold-
easily lead to the filing of the samples taken, for purposes of “information management” or further research, making such samples available for DNA testing. Furthermore, there is increased interest in routine genetic screening of newborn babies for genetic disorders.\footnote{412} If a sample of DNA was taken from all babies at birth and access was readily granted on a showing of need, diagnostic research could be conducted efficiently, the FBI could quickly build its databank for investigation purposes, and future issues of identity, in the cases of missing persons discovered, illegitimacy, paternity, or immigration, could be easily resolved. Thus, the move from a databank of DNA profiles on released felons to those on other members of society is not a remote possibility.

Law enforcement officials are naive in their narrow concept of the scope of DNA profiling. FBI Director William Sessions claimed that only criminal, not behavioral or medical, aspects of the profile would be kept on file.\footnote{413} It may be true that at present scientists can only discern from the autoradiograph that certain alleles are present, the functions of which are unknown. In the future, however, scientists may know what each allele encodes. Furthermore, if DNA base sequencing becomes the preferred test, then the exact coding of part or all of a person’s genome would be on file, making the separation of the “criminal” from the “behavioral” or the “medical” impossible. In addition, some jurisdictions such as California plan to have not only the results, but also the actual sample, on file.\footnote{414} In that case, new tests can always be performed to reveal additional information.

Judge Sessions also promised that the FBI would carefully guard the information.\footnote{415} However, New York University Law Professor Donald Shapiro claimed that the FBI’s fingerprinting system has been compromised before, and, as long as the information exists, it can be leaked.\footnote{416} Social security numbers are no longer private.\footnote{417} In the future the preferred form of identification, rather than a social security number or a driver’s license or a military dog tag, could be a plastic card with a com-
puterized version of an individual’s DNA profile. This information could become as accessible as a driver’s license.

Steps must be taken to minimize the possibility of leakage or abuse of the potentially sensitive and personal information contained in a DNA databank. The American Civil Liberties Union of Washington State, along with Professor Bereano, took the lead in drafting a policy on the creation of the databanks. Among the policy guidelines: DNA should be extracted from only a narrow category of individuals; the DNA profile should be stored in a form that minimizes the retention of extraneous information; use of the sample should be restricted to its intended purpose; access to the information should be limited to designated public officials and only for the limited extent needed; the sample and record should be destroyed once their purposes have been served or the criteria justifying the taking of the sample no longer apply; an individual has a right of access to her DNA sample; and an individual has a right to prior, informed, and voluntary consent for the use of the sample for a purpose other than the one for which it was taken.418

The compiling of a DNA profiling databank cannot be viewed as an innocuous, objective procedure. At different times, the databank could have different meanings. Although in a time of heightened awareness of the rights of individuals the databank may be safe from abuse, in a time of drug testing, war on crime, and increasing trust in technology despite the shock of technological disasters such as Chernobyl and the Challenger,419 the potential for abuse of the databank for the sake of “efficiency” or the “public good” may be heightened. John Hicks claimed that “[t]he use of DNA technology in law enforcement when applied in a responsible and well-coordinated manner with due consideration for the needs of our criminal justice system will enhance the effectiveness, efficiency and productivity at all levels”420 and “enhanc[e] the Nation’s effort to combat violent crime.”421 Individuals’ need for privacy and security is conspicuously absent from this description of heightened efficiency. In the words of Professor Bereano:

Civil liberties depend essentially on a celebration of notions of diversity. Technological rationality, on the one hand, depends upon notions of uniformity—being able to put things in a small number of categories—keeping them there, and tracking and monitoring them. . . . We must be ready to recognize that freedom flourishes best

418. Washington American Civil Liberties Union, DNA Extraction and Analysis in the Criminal Context (attached as exhibit to Bereano Testimony, supra note 394) (on file with the Stanford Law Review).

To address such individual liberty concerns, the California law includes restrictions that the data obtained be released only to criminal investigators and prosecutors. However, it also provides exceptions for research, provided the subject is not identifiable, and for inclusion in transcripts or public records when authorized by a court or statute. 1989 Cal. Stat. —, Ch. 1304.

419. See Bereano Testimony, supra note 394, at 3.

420. Hicks Testimony, supra note 405, at 11.

421. Id. at 4.
in an inefficient society, that many of the freedoms that we enjoy as a practical matter are exercised in the interstices of the kind of matrix that governments, with their new technologies, are able to establish and control to monitor their citizens.422

The rights of the criminal defendant were not designed for "the deviant," but for every member of society. The erosion of the rights of the criminal defendant through the unrestrained use of scientific technology such as DNA profiling threatens to shake the foundations of a free society. We must not allow our excitement over technological advances to overshadow principles of justice or the integrity of the individual.

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DNA profiling evidence is currently scientifically unreliable for application to forensics. Expert testimony in the Castro case highlighted the potential for error in declaring matches and cast doubt on the reliability of the outrageous statistical claims of the technique's proponents. Due to the novelty of the technique’s application to forensics, testimony from unbiased expert witnesses who are familiar with the unique difficulties of the forensic technique is sorely lacking.

There is an urgent need for the scientific community to review the DNA profiling technique and designate uniform controls and standards to ensure accuracy in the declarations of matches. Judges, prosecutors, juries and the press have been too excited about the evidence to understand the significance of the technical challenges in Castro. Only after the scientific community determines that forensic DNA profiling is a reproducible, reliable test, and only after those laboratories which plan to employ the test demonstrate proficiency, will the criminal defendant receive justice. We must not allow our enthusiasm for scientific and technological advances to overshadow our commitment to the Bill of Rights and to a fair and just society.

422. Bereano Testimony, supra note 394, at 5.