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The Admissibility of DNA Evidence: Minnesota No Longer Stands Alone

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COMMENTS

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I. INTRODUCTION

Only six years have passed since DNA evidence was first admitted in a criminal trial in this country.¹ Since that time, DNA evidence has engendered controversy, its scientific reliability and legal applicability debated by both the scientific and legal communities.² DNA evidence has been acclaimed as "the greatest single advance in the search for truth, conviction of the guilty, and acquittal of the innocent since the advent of cross-examination"³ and attacked as an unreliable and unproven scientific technique that turns "courtrooms into laboratories and defendants into guinea pigs."⁴

In Minnesota, the debate has engaged both the legislature and the courts. The Minnesota Legislature, in 1989, expressly declared that the results of DNA analysis and statistical population frequency evidence were admissible in a civil or criminal trial.⁵ Minnesota courts, however, refused to admit evidence showing a statistical match between the DNA of a defendant and the DNA found at the crime

1. Forensic DNA evidence was first found admissible in *Andrews v. State*, 533 So. 2d 841, 850 (Fla. Dist. Ct. App. 1988), *rev. denied*, 542 So. 2d 1332 (Fla. 1989). DNA evidence was previously found admissible in England in 1987. *See infra* note 47 and accompanying text.

2. For an excellent discussion of the current debate, including recommendations, see COMMITTEE ON DNA TECHNOLOGY IN FORENSIC SCIENCE, NATIONAL RESEARCH COUNCIL, *DNA TECHNOLOGY IN FORENSIC SCIENCE* (1992).

3. LORNE T. KIRBY, *DNA FINGERPRINTING: AN INTRODUCTION* xv (1990) (paraphrasing *People v. Wesley*, 533 N.Y.S.2d 643, 644 (Albany County Ct. 1988)).

4. Janet C. Hoeffel, Note, *The Dark Side of DNA Profiling: Unreliable Scientific Evidence Meets the Criminal Defendant*, 42 STAN. L. REV. 465, 467 (1990).

5. MINN. STAT. §§ 634.25, 634.26 (1992) (codifying Act of Aug. 1, 1989, ch. 290, art. 4, §§ 18,19, 1989 Minn. Laws 1624). These statutes provide:

In a civil or criminal trial or hearing, the results of DNA analysis, as defined in section 299C.155, are admissible in evidence without antecedent expert testimony that DNA analysis provides a trustworthy and reliable method of identifying characteristics in an individual's genetic material upon a showing that the offered testimony meets the standards for admissibility set forth in the Rules of Evidence.

MINN. STAT. § 634.25 (1992).

In a civil or criminal trial or hearing, statistical population frequency evidence, based on genetic or blood test results, is admissible to demonstrate the fraction of the population that would have the same combination of genetic markers as was found in a specific human biological specimen. "Genetic marker" means the various blood types or DNA types that an individual may possess.

MINN. STAT. § 634.26 (1992).

scene.⁶ This debate led to several legislative proposals for a constitutional amendment requiring the admission of relevant statistical evidence.⁷ In April 1994, the Minnesota Supreme Court responded by lifting the ban on the previously excluded DNA statistical evidence.⁸

In order to better understand this debate, this Comment will take an in-depth look at forensic DNA evidence. Part II examines the theories and background of DNA evidence and the methodology used to isolate and identify DNA. Part III sets out the tests used by state and federal courts to determine the admissibility of DNA evidence. Part IV identifies which courts admit and which do not admit forensic DNA evidence and the reasons for their decisions. Part IV also examines Minnesota's prior and current positions on DNA evidence. Part V provides a brief summary of the status of DNA evidence admissibility.

II. DNA IDENTIFICATION ANALYSIS

A. *The Theory*

1. *DNA Composition and Structure*

The human body is composed of approximately 100 trillion cells.⁹ Each cell serves as a "microfactory," taking in raw materials, producing new substances, and disposing of wastes.¹⁰ Each cell also has the ability to replicate itself, using a "blueprint" found within the nucleus of the cell.¹¹ This unique blueprint is called deoxyribonucleic acid or DNA.

Within the cell nucleus, DNA is packed into structures called chromosomes.¹² Each human cell contains twenty-three pairs of chromo-

6. *State v. Schwartz*, 447 N.W.2d 422, 428-29 (Minn. 1989) (admitting the test results but not the statistical evidence because of the danger that the jury will use the evidence as a measure of the probability of the defendant's guilt or innocence). *See also* *State v. Johnson*, 498 N.W.2d 10, 15 (Minn. 1993); *State v. Nielsen*, 467 N.W.2d 615, 620 (Minn. 1991).

7. *See, e.g.*, S. 1871, 78th Leg., 1993-94 Reg. Sess. § 12 (1994) which proposes: "Sec. 12. Statistical frequency evidence based on deoxyribonucleic acid (DNA) testing, including the fraction of the population having the same combination of genetic characteristics, shall be admissible, if relevant, in any judicial proceeding." *See infra* part IV.C for a more detailed discussion of Minnesota's treatment of forensic DNA identification analysis.

8. *State v. Bloom*, No. C9-94-55, 1994 WL 169980, at *1 (Minn. Apr. 29, 1994).

9. KIRBY, *supra* note 3, at 8.

10. *Id.*

11. *Id.* The nucleus is a membrane-bound structure found within most cells. The nucleus contains an individual's hereditary information and acts as the control center of cell function. JEFFREY J.W. BAKER & GARLAND E. ALLEN, *THE STUDY OF BIOLOGY* G-18 (3d ed. 1978).

12. Dan L. Burk, *DNA Fingerprinting: Possibilities and Pitfalls of a New Technique*, 28 *JURIMETRICS J.* 455, 457 (1988). The sum total of genetic information found within the chromosomes is called the genome. This genetic information determines an individual's physical characteristics. *Id.*

somes¹³ within its nucleus.¹⁴ One half of each pair of chromosomes is provided by each parent at the time of conception.¹⁵ Each chromosome contains two parallel strands¹⁶ of DNA joined in such a way as to resemble a twisted ladder or zipper.¹⁷ Linking the two strands are pairs of molecules called bases.¹⁸ These base pairs form the rungs of the ladder or the teeth of the zipper.¹⁹

Four types of bases are found in DNA: adenine, guanine, cytosine, and thymine.²⁰ DNA base pairing is complementary and specific; adenine pairs only with thymine and guanine pairs only with cytosine.²¹ In order, therefore, for a single DNA strand to pair with a second DNA strand, each base along the first strand must be complementary to its matching base on the second strand.²²

2. DNA Function

DNA has two distinct functions. The first is to serve as a blueprint for assembling individual amino acids into proteins.²³ The sequence of bases found on the DNA molecule determines which amino acids

13. Technically, each cell nucleus contains 22 matched pairs of autosomal, or non-sex, chromosomes and two sex chromosomes, for a total of 46 chromosomes. KIRBY, *supra* note 3, at 8.

14. DNA is found in all cells that contain a nucleus. Certain cells, such as red blood cells, do not have a nucleus and, therefore, do not contain DNA. William Thompson & Simon Ford, *DNA Typing: Acceptance and Weight of the New Genetic Identification Tests*, 75 VA. L. REV. 45, 61 n.76 (1989).

15. KIRBY, *supra* note 3, at 8.

16. The strands are composed of sugar and phosphate molecules. Thompson & Ford, *supra* note 14, at 62. The sugar molecule is a five-carbon or pentose sugar known as deoxyribose. BAKER & ALLEN, *supra* note 11, at 612.

17. Burk, *supra* note 12, at 457. It was the Englishman, Dr. Francis Crick, and his American colleague, Dr. James Watson, who first developed the model for the DNA molecule in the 1950s. According to the model, two strands of DNA are wound into a right-handed double helix. ERIC E. CONN & P.K. STUMPF, *OUTLINES OF BIOCHEMISTRY* 130 (4th ed. 1976). See also J.D. Watson & F.H.C. Crick, *Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid*, 171 SCI. 737, 737 (1953).

18. CONN & STUMPF, *supra* note 17, at 737. There are approximately three billion base pairs in a human DNA molecule. Barry W. Duceman, *DNA Analysis: Scientific and Legal Aspects*, 2 ALB. L.J. SCI. & TECH. 53, 57 (1992).

19. Burk, *supra* note 12, at 457.

20. KIRBY, *supra* note 3, at 9. The bases are referred to by their first letters: A, G, C, and T. *Id.*

21. Burk, *supra* note 12, at 457.

22. *Id.* A double-stranded DNA fragment could be represented as follows:

```

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

```

23. KIRBY, *supra* note 3, at 11.

will be joined together to form a particular protein.²⁴ The sequence of bases that controls the assembly of one protein is called a gene.²⁵

While the genes for most proteins are the same within a given species, certain genes occur in different forms in different individuals.²⁶ These genes are known as polymorphic genes,²⁷ and their location on the DNA molecule is called a polymorphic site or locus.²⁸ When comparing individuals, about 99.9% of the DNA molecules are identical.²⁹ But since each DNA molecule contains over three billion base pairs, a 0.1% difference translates to about three million base pair differences in any given individual.³⁰ Because of this variability, no two individuals, with the exception of identical twins, will have identical DNA.³¹

The second DNA function is to serve as a template in cell reproduction.³² Before a cell can divide, a copy of the existing cell's DNA molecule must be made for the new cell.³³ During the replication process, each DNA molecule "unzips" into two parent strands.³⁴ Each parent strand then serves as a template for the synthesis of a corresponding

24. ARTHUR J. VANDER ET AL., *THE MECHANISMS OF BODY FUNCTION* 51 (3d ed. 1980). Proteins are the building blocks that form the structure of most organs in the body. Proteins also play a critical role in almost all chemical interactions occurring in the body. *Id.* at 35-36.

25. *Id.* at 51. The sequence of bases can be compared to a written language such as English. The letters are arranged in specific sequences to form words and sentences. In the DNA molecule there are only four letters, A, G, C, and T; each letter corresponds to one of the four bases. A DNA "word" consists of a three-base sequence or triplet. Each triplet signifies an amino acid. A DNA "sentence" (or gene) is a sequence of triplets (or "words") that specify the amino acids for a particular protein. *Id.* at 51-52. For example, the triplet "TTC" codes for the amino acid lysine. CONN & STUMPF, *supra* note 17, at 537.

26. KIRBY, *supra* note 3, at 24-26.

27. Polymorphism simply means that a basic structure (such as a gene) is able to assume different forms. One example of a polymorphism is the human ABO blood group system. Instead of just one blood type, there are four: O, A, B, and AB. *Id.* at 24-25. The various forms of the polymorphic genes are called alleles. If many alleles exist for a polymorphic site, the site is referred to as a hypervariable site or locus. Duceman, *supra* note 18, at 59.

28. KIRBY, *supra* note 3, at 24. The terms locus and site can be used interchangeably.

29. Duceman, *supra* note 18, at 59.

30. *Id.* These base pair differences occur at the polymorphic sites in the DNA molecule. *Id.*

31. Thompson & Ford, *supra* note 14, at 61.

32. KIRBY, *supra* note 3, at 13. Cells reproduce by dividing. One parent cell becomes two identical daughter cells, each containing the same quantity of genetic material as the parent cell. Reproductive cells are the exception to this rule. One reproductive parent cell divides to produce four eggs or sperm, each containing one-half the genetic material of the parent. *Id.* at 327. At conception, the quantity of genetic material is made whole in the embryo. *Id.* at 13.

33. *Id.* at 13.

34. *Id.* at 13, 16.

daughter strand.³⁵ The two resulting DNA molecules are identical to each other with each molecule consisting of one parent strand and one daughter strand.³⁶

Since all cells are ultimately derived from one cell, the fertilized egg, all cells in the body contain identical DNA.³⁷ For example, DNA taken from an individual's saliva is the same as that found in the blood or semen.³⁸ And except for rare mutations which may occur within the DNA sequence, DNA remains constant throughout a person's lifetime.³⁹ These qualities, along with the fact that no two persons have identical DNA, provide the basis for the DNA identification analysis.⁴⁰

B. *The Methodology*

1. *Background*

DNA identification analysis⁴¹ is the process of isolating and identifying certain segments of the DNA molecule.⁴² The technique was developed for, and continues to be used by, the scientific community as part of the study of human genetics.⁴³ The foundation for DNA identification analysis was established in 1980 with the discovery that the same DNA segment has different lengths in different individuals.⁴⁴ The analysis technique was first used in 1985 to identify matching samples of human DNA.⁴⁵

35. *Id.*

36. *Id.*

37. While each nucleus contains a complete DNA blueprint for the entire body, no cell uses the entire blueprint. Each cell uses only those sections of DNA needed to perform that cell's particular function. Burk, *supra* note 12, at 457.

38. KIRBY, *supra* note 3, at 1.

39. Thompson & Ford, *supra* note 14, at 62.

40. KIRBY, *supra* note 3, at 1.

41. DNA identification analysis is also referred to as DNA testing, DNA identity testing, DNA profiling, DNA fingerprinting, DNA typing, and DNA genotyping. *Id.*

42. Thompson & Ford, *supra* note 14, at 63.

43. Burk, *supra* note 12, at 455.

44. KIRBY, *supra* note 3, at 2.

45. Lisa B. Hansen, Note, *Stemming the DNA Tide: A Case for Quality Control Guidelines*, 16 HAMLINE L. REV. 211, 213 (1992). Identification was made by Dr. Alec Jeffreys, a British geneticist and originator of the DNA fingerprinting technique. BUREAU OF JUSTICE STATISTICS, U.S. DEP'T OF JUSTICE, FORENSIC DNA ANALYSIS: ISSUES 4 (1991). See Alec J. Jeffreys et al., *Hypervariable "Minisatellite" Regions in Human DNA*, 314 NATURE 67 (1985).

Forensic DNA identification analysis⁴⁶ was first used in England in 1987.⁴⁷ In the United States, DNA evidence was first admitted in court to identify a criminal suspect in 1988.⁴⁸ Forensic DNA identification analysis is also used in paternity testing⁴⁹ and identification of missing persons.⁵⁰

2. Analysis Techniques

DNA identification analysis is performed by government agencies and several private firms.⁵¹ The analysis techniques most commonly used in forensic DNA testing are the Restriction Fragment Length Polymorphism (RFLP) analysis and the Polymerase Chain Reaction (PCR) amplification (also called the Allele Specific Probe analysis).⁵² RFLP is the more widely used method and is the one currently used by the FBI laboratories.⁵³

46. The DNA identification analysis discussed in this Comment is the forensic application of DNA identification analysis as opposed to its scientific application. Some examples of the scientific application include: tumor and disease analysis, identification of microorganisms, family trait identification, paternity testing, determination of detrimental or valuable traits in livestock, studies of evolution, wildlife poaching, and plant breeding. See generally KIRBY, *supra* note 3, at 226-53.

47. Duceman, *supra* note 18, at 56. The English case, a serial rape and murder, is described in Joseph Wambaugh's, *THE BLOODING* (1989). During the criminal investigation, one suspect was exonerated when it was found that his DNA did not match the DNA obtained from the crime scene. After the suspect was exonerated, the police took blood samples from more than 5000 males in three surrounding villages before finding a DNA match. FORENSIC DNA ANALYSIS, *supra* note 45, at 8. An English court was also the first in the world to convict on DNA evidence. In November 1987, Robert Melias was convicted of rape and sentenced to eight years in jail. *Id.* at 4 n.8.

48. *Andrews v. State*, 533 So. 2d 841, 843, 849 (Fla. Dist. Ct. App. 1988), *review denied*, 542 So. 2d 1332 (Fla. 1989). The defendant was convicted of aggravated battery, sexual battery, and armed burglary after admission of DNA evidence. The admissibility of the DNA evidence and the conviction were affirmed on appeal. *Id.* at 842.

49. KIRBY, *supra* note 3, at xv; FORENSIC DNA ANALYSIS, *supra* note 45, at 7.

50. KIRBY, *supra* note 3, at 228-29.

51. Hansen, *supra* note 45, at 215 n.40. See also FORENSIC DNA ANALYSIS, *supra* note 45, at 10 (indicating that the FBI and various states have forensic laboratories in operation).

The private firms, each established in 1987, are Lifecodes Corporation, Tarrytown, New York; Cellmark Diagnostic Corporation, Germantown, Maryland; and Cetus Corporation, Emeryville, California. Lifecodes and Cellmark use the RFLP analysis technique. See *infra* part II.B.2.a. for a discussion of the RFLP analysis technique. Lifecodes uses four single-locus probes, each of which produces one or two bands. Cellmark uses single-locus probes for criminal identifications and multi-locus probes for paternity cases. Cetus developed the PCR amplification technique. See Duceman, *supra* note 18, at 56 n.19. See *infra* part II.B.2.b. for a discussion of the PCR amplification technique. See also Thompson & Ford, *supra* note 14, at 48-50.

52. Thompson & Ford, *supra* note 14, at 64.

53. Hansen, *supra* note 45, at 215.

Both methodologies start with a sample collection.⁵⁴ A sample can be from either fresh or dried tissue.⁵⁵ Fresh tissue includes whole blood, scrapings from the inner cheek surface, semen, and hair follicles.⁵⁶ Dried samples include blood and semen stains, tooth pulp, and bone marrow.⁵⁷ Autopsy specimens can also be used as a DNA source.⁵⁸

Once the specimen is collected, the test used depends on the amount and quality of the available sample.⁵⁹ While the PCR test requires far less biological material than does an RFLP analysis, the PCR test results are less specific.⁶⁰ The PCR test also relies on newer technology that is less well-accepted by both the scientific community and the courts.⁶¹

54. Samples are taken from the victim and crime scene and a blood sample is taken from a suspect. Taking a blood sample from a suspect or defendant without the individual's permission has raised constitutional questions of due process and self-incrimination. Suzanne H. Stenson, Comment, *Admit It! DNA Fingerprinting is Reliable*, 26 HOUS. L. REV. 677, 696-97 (1989). However, the United States Supreme Court generally holds that such actions are constitutional. *Id.* For instance, police may determine an unconscious person's intoxication level through blood samples taken without a warrant. *See, e.g.,* *Breithaupt v. Abram*, 352 U.S. 432, 435-38 (1954) (finding that such tests are common and minimally intrusive). The Court has also held that blood samples may be taken without a warrant if the situation involves exigency and probable cause. *See, e.g.,* *Schmerber v. California*, 384 U.S. 757, 768-70 (1966).

55. KIRBY, *supra* note 3, at 51.

56. *Id.* at 51.

57. *Id.*

58. *Id.*

59. FORENSIC DNA ANALYSIS, *supra* note 45, at 4. RFLP analysis requires at least 10 to 50 nanograms (one billionth of a gram) of DNA. KIRBY, *supra* note 3, at 127. One milliliter of fresh whole blood or a stain larger than the size of a dime is generally needed to provide the minimum amount of DNA. *Id.* at 52. PCR amplification analysis can be used for samples that are smaller, even as small as one cell. *Id.* at 78, 127.

60. Thompson & Ford, *supra* note 14, at 50. RFLP analysis yields a series of bands whose probability of occurrence is calculated from population frequency data. KIRBY, *supra* note 3, at 164-68. RFLP analysis utilizes actual DNA extracted from the biological sample tested. *Id.* at 2.

PCR analysis yields a series of dots that indicate whether a particular allele is present or absent in the sample DNA. Thompson & Ford, *supra* note 14, at 50. PCR analysis utilizes DNA that is chemically multiplied from a biological sample containing too little DNA mass for RFLP analysis. *Id.* See also *infra* part II.B.2.b. for a description of the PCR amplification test.

61. DNA TECHNOLOGY, *supra* note 2, at 70 (explaining that PCR has not yet achieved full acceptance in the forensic setting). DNA evidence based on the PCR test has been admitted thus far in only five states. *New Jersey, State v. Williams*, 599 A.2d 960, 968 (N.J. Super. Ct. 1991); *Ohio, State v. Penton*, No. 9-91-25, 1993 WL 102507, at *5 (Ohio Ct. App. April 7, 1993); *Oregon, State v. Lyons*, 863 P.2d 1303, 1311 (Or. Ct. App. 1993); *Texas, Clarke v. State*, 813 S.W.2d 654, 655 (Tex. Ct. App. 1991); *Virginia, Spencer v. Commonwealth*, 393 S.E.2d 609, 621 (Va. 1990). See *infra* note 300 for a listing of states that admit DNA evidence.

a. RFLP Analysis

The goal of RFLP analysis is to cleave the DNA molecule at certain target sites and identify any resulting fragments that contain key polymorphic segments.⁶² The analysis produces a print consisting of a pattern of visible bands.⁶³

i. Extraction

The first step in the analysis is to extract the DNA from the tissue sample.⁶⁴ In this part of the process, the sample is subjected to chemical and enzymatic processes which break open the cells, remove any contaminating substances, and release the DNA.⁶⁵

ii. Fragmentation

Next, the extracted DNA molecule is cut into smaller segments by protein molecules called restriction enzymes.⁶⁶ These enzymes recognize a specific base sequence,⁶⁷ or restriction site, along the DNA molecule and cut the molecule at that site.⁶⁸ The location of these restriction sites and the resulting DNA fragment lengths produced by the cleavage differ among individuals.⁶⁹

62. Thompson & Ford, *supra* note 14, at 64.

63. *Id.* at 48.

64. *Id.* at 65.

65. *Id.*; see also KIRBY, *supra* note 3, at 55.

66. Burk, *supra* note 12, at 457. There are hundreds of restriction enzymes; each one recognizes and cleaves a different base sequence. KIRBY, *supra* note 3, at 23.

67. See *supra* notes 20-25 and accompanying text for a discussion of base sequences.

68. Burk, *supra* note 12, at 457.

69. Thompson & Ford, *supra* note 14, at 67-68. The difference in fragment length is due to the existence of "minisatellites" located between restriction enzyme sites. Minisatellites consist of a number of repeated base sequences located in tandem at certain sites on the DNA. These base sequences are not recognized by the restriction enzyme, and the number of repeated sequences varies from one individual to another. Hoeffel, *supra* note 4, at 472. The variations in the number of repeated base sequences creates the difference in fragment lengths. Burk, *supra* note 12, at 463. The variations in number of repeated base sequences are referred to as "variable number of tandem repeats" or VNTR. KIRBY, *supra* note 3, at 342.

iii. *Sorting*

Gel electrophoresis⁷⁰ is the next step. This technique sorts the DNA fragments according to their length.⁷¹ Samples of the fragmented DNA are placed at one end of an agarose gel,⁷² and an electric current is passed through the gel.⁷³ Because DNA fragments have a negative electrical charge, they will be drawn toward the positive pole at the far end of the gel.⁷⁴ The length of each fragment determines the distance the fragment will move.⁷⁵ Shorter fragments are lighter in weight and will move more quickly through the gel.⁷⁶ When the current is turned off, the shorter fragments will be grouped toward the positive pole and the longer fragments toward the negative pole.⁷⁷

The fragments are then chemically "unzipped" in a process that separates the double-stranded fragments of DNA into two separate strands by unhooking each base from its complement.⁷⁸ The individual fragment strands are then transferred to a nylon membrane by a procedure called Southern blotting.⁷⁹ The order and placement of the fragment strands on the membrane is identical to that in the gel.⁸⁰

iv. *Identification*

The next step is to locate any fragments with the desired polymorphic genes.⁸¹ Because the fragments are too small to be seen, a DNA probe is used to visualize the fragments.⁸² A probe is a short

70. Electrophoresis is a laboratory procedure used for separating electrically-charged particles. The particles are placed in a trough to which a thin layer of gel has been added. See *infra* note 72 for a description of the gel. The application of an electric current will create a negatively-charged pole and a positively-charged pole at opposite ends of the gel. Any negatively-charged particles in the gel will move toward the positive pole; any positively charged particles will move toward the negative pole. BAKER & ALLEN, *supra* note 11, at 114.

71. Burk, *supra* note 12, at 459.

72. The gel resembles a thin slab of Jell-O. *Id.* Agarose is an agar gel commonly used in gel electrophoresis. Agar is extracted from certain seaweeds. KIRBY, *supra* note 3, at 325.

73. Burk, *supra* note 12, at 459.

74. *Id.*

75. Thompson & Ford, *supra* note 14, at 69.

76. KIRBY, *supra* note 3, at 96.

77. Burk, *supra* note 12, at 460.

78. Thompson & Ford, *supra* note 14, at 71.

79. KIRBY, *supra* note 3, at 101. The transfer from the gel to the more stable nylon membrane is done to preserve the order and placement of the DNA fragments and to allow subsequent handling. Duceman, *supra* note 18, at 61. A salt solution is used to effect the transfer. KIRBY, *supra* note 3, at 340. The transfer technique is named after its inventor, Edward Southern. *Id.* at 101.

80. Burk, *supra* note 12, at 460.

81. See *supra* note 27 and accompanying text for an explanation of polymorphic genes.

82. Burk, *supra* note 12, at 459-60.

segment of single-stranded DNA that has been radioactively tagged.⁸³ The probe is designed to complement and bind to a single-stranded base sequence appearing in, or adjacent to, a highly polymorphic site.⁸⁴ Two different types of probes are used. A single-locus probe will pair with a complimentary segment that occurs at only one polymorphic site on the DNA molecule.⁸⁵ Multi-locus probes seek out DNA base sequences that occur at several such polymorphic locations.⁸⁶

Once placed on the membrane, the probe seeks out and "hybridizes"⁸⁷ any complementary single-stranded DNA fragment that is found on the membrane.⁸⁸ When an X-ray film is placed in contact with the membrane, the radioactive probe exposes the film as a dark band at the point where the probe hybridized with its complimentary DNA fragment.⁸⁹

If one single-locus probe is used, the X-ray, or autoradiograph,⁹⁰ shows one or two bands.⁹¹ If a multi-locus probe is used, a number of bands will appear on the autoradiograph.⁹² The location of each band on the autoradiograph indicates how far that DNA segment migrated in the gel, which in turn indicates the length of the fragment.⁹³ The pattern of bands on the autoradiograph is similar to the bar code found on food packaging.⁹⁴

v. Interpretation

The next step is the interpretation of the completed autoradiograph. In criminal cases, the pattern of bands produced by the sus-

83. Stenson, *supra* note 54, at 680-81. Probes are created in the laboratory using recombinant DNA technology. Burk, *supra* note 12, at 460.

84. Hoeffel, *supra* note 4, at 473.

85. *Id.*

86. *Id.*

87. Hybridization is the pairing of complimentary strands of DNA which have been derived from different sources. KIRBY, *supra* note 3, at 110, 333.

88. Stenson, *supra* note 54, at 680.

89. Burk, *supra* note 12, at 460.

90. An autoradiograph is an X-ray film that has been exposed to a radioactive source. KIRBY, *supra* note 3, at 326.

91. Hansen, *supra* note 45, at 218. If an individual is homozygous (has identical alleles at the corresponding chromosome loci), cleavage by a restriction enzyme will produce fragments of the same length. If an individual is heterozygous (has different alleles at the corresponding chromosome loci), cleavage will produce fragments of two different lengths. The number of bands reflects the number of different fragment lengths. KIRBY, *supra* note 3, at 339.

92. Hansen, *supra* note 45, at 218. Usually fifteen bands will appear. Thompson & Ford, *supra* note 14, at 72.

93. Thompson & Ford, *supra* note 14, at 74. The presence of bands at different locations due to fragment length differences is called restriction fragment length polymorphism. Burk, *supra* note 12, at 461.

94. Thompson & Ford, *supra* note 14, at 87 n.188.

pect's DNA is compared to the pattern obtained from the crime scene samples.⁹⁵ The patterns are first compared visually by an analyst to determine whether a match can be excluded.⁹⁶ If a possible match is found, it is confirmed by means of a computer-assisted image analysis.⁹⁷ In this procedure, the band positions are converted into numerical codes and the codes are then compared.⁹⁸

vi. Probability Calculation

The final step is a statistical probability calculation. If a match is found, the uniqueness of the band pattern is statistically calculated for a specified population.⁹⁹ This is done by comparing the matched band patterns against a database of band patterns previously obtained by using the same probe in the same racial population.¹⁰⁰ If more than one probe is used, a comparison is made for the band pattern produced by each probe.¹⁰¹ The final statistic is expressed in terms of the probability that this match would occur by chance in this population group.¹⁰²

b. PCR Amplification Analysis

A second method of DNA identification analysis is Polymerase Chain Reaction (PCR) amplification (also called Allele Specific Probe analysis).¹⁰³ This test determines whether certain polymorphic genes, or alleles,¹⁰⁴ are present in a DNA sample.¹⁰⁵ Allele-specific probes are used to detect these alleles.¹⁰⁶ Because the technique is able to replicate DNA, much smaller samples can be used than in RFLP analysis.¹⁰⁷

95. Duceman, *supra* note 18, at 62.

96. *Id.*

97. *Id.*; see also KIRBY, *supra* note 3, at 116.

98. KIRBY, *supra* note 3, at 116-19.

99. Hoeffel, *supra* note 4, at 474. See *infra* part II.B.4.b.ii. for a discussion of the calculations.

100. Duceman, *supra* note 18, at 83-84.

101. *Id.* at 64.

102. Hoeffel, *supra* note 4, at 474. For example, an allele might occur in one out of every 350 members of a given population. This allele has a frequency of one in 350.

103. The test is also called the Cetus test after its developer, Cetus Corporation. Thompson & Ford, *supra* note 14, at 49-50.

104. An allele is one of several alternate forms of a polymorphic gene. KIRBY, *supra* note 3, at 325. See also *supra* note 27.

105. Thompson & Ford, *supra* note 14, at 76.

106. *Id.* Whereas the RFLP test measures and identifies the different DNA fragment lengths produced at a specific polymorphic site, the PCR test only determines whether a particular allele is present or absent in the sample DNA. KIRBY, *supra* note 3, at 337, 339.

107. Stenson, *supra* note 54, at 684 n.68. One milliliter of fresh blood or a dried stain larger than a dime is needed for the RFLP analysis. KIRBY, *supra* note 3, at 52. For smaller samples, PCR amplification analysis may be the only option for obtaining sufficient DNA for analysis. *Id.* at 76.

i. Amplification

As with RFLP analysis, DNA is first extracted from the sample and purified.¹⁰⁸ The DNA is then duplicated or “amplified.”¹⁰⁹ In the amplification process,¹¹⁰ a primer¹¹¹ is attached at both ends of the DNA segments that are to be amplified.¹¹² A heat-stable enzyme¹¹³ is added and the solution is exposed to heating and cooling cycles.¹¹⁴ From one or two segments of DNA, the process can replicate up to 10 million copies within a few hours.¹¹⁵

ii. Identification

The amplified DNA is then added to a nylon membrane¹¹⁶ that has been dotted with a variety of allele-specific probes.¹¹⁷ If the allele of interest is present in the dotted area, the probe will bind to the allele, and a visible dot will appear on the membrane.¹¹⁸ When a radioactive probe is used, the dot will expose X-ray film placed in contact with the membrane.¹¹⁹

iii. Interpretation

The use of an allele-specific probe may or may not produce a dot, depending on whether the allele of interest is present on the membrane. The test simply provides a yes or no answer.¹²⁰ If the suspect does not have alleles matching those found at the crime scene, the suspect can be excluded.¹²¹

The presence of a matching allele, however, does not necessarily mean that the samples came from the same individual.¹²² Since the allele of interest may be shared by a substantial percentage of the population, a match merely places the suspect within the percentage of the

108. Thompson & Ford, *supra* note 14, at 76.

109. *Id.*

110. The amplification process is called polymerase chain reaction. *Id.*

111. A primer is a short segment of purified DNA. It forms the foundation on which the sample DNA can be replicated. FORENSIC DNA ANALYSIS, *supra* note 45, at 6.

112. KIRBY, *supra* note 3, at 76.

113. The enzyme used, Taq polymerase, serves as a catalyst in the amplification process. *Id.* at 76, 341.

114. *Id.* at 76.

115. Thompson & Ford, *supra* note 14, at 77.

116. Gel electrophoresis and Southern Blot are not needed for PCR Amplification analysis. KIRBY, *supra* note 3, at 91.

117. Thompson & Ford, *supra* note 14, at 78.

118. KIRBY, *supra* note 3, at 104.

119. *Id.* at 115.

120. Thompson & Ford, *supra* note 14, at 78.

121. FORENSIC DNA ANALYSIS, *supra* note 45, at 7.

122. *Id.*

population that shares that allele.¹²³ A series of probes is used to further narrow the population group.¹²⁴

3. Uses and Advantages

DNA identification analysis is used in forensic analysis, paternity testing, diagnostic medicine, and plant and animal science.¹²⁵ Because DNA can be recovered from the human body long after death, DNA also can be used to identify human remains and to establish bloodlines.¹²⁶

DNA identification analysis has several advantages over the more traditional biological identification procedures such as ABO blood typing,¹²⁷ human leukocyte antigen (HLA) typing,¹²⁸ or typing of red cell enzymes and serum proteins.¹²⁹ The first advantage is DNA specificity.¹³⁰ The ABO blood test, for example, can exclude a suspect if one of the samples is a different blood type.¹³¹ But since many individuals have the same blood type, two samples with the same blood type do not necessarily indicate that both samples had a common source.¹³² In contrast, if two DNA samples match, the probability is very high that the samples came from the same source.¹³³

123. *Id.* at 6, 7.

124. *Id.* at 6.

125. KIRBY, *supra* note 3, at xv.

126. See Stenson, *supra* note 54, at 681; Thompson & Ford, *supra* note 14, at 45 n.3.

127. In ABO blood typing, a blood sample is tested to determine to which of four possible blood types it belongs: O, A, B, or AB. PAUL C. GIANNELLI & EDWARD J. IMWINKELRIED, *SCIENTIFIC EVIDENCE* 575-86 (1986). The ABO symbols refer to antigens found on the red blood cell surface. KIRBY, *supra* note 3, at 25. An antigen is a substance that can incite the production of an antibody. EUGENE W. NESTER ET AL., *MICROBIOLOGY* 380 (2d ed. 1973). For Caucasians, the approximate frequencies for each of the four blood types are: O - 44%; A - 43%; B - 10%; AB - 2%. Thompson & Ford, *supra* note 14, at 51 n.36.

128. HLA typing tests for certain antigens found on the surface of white blood cells. GIANNELLI & IMWINKELRIED, *supra* note 127, at 586-89.

129. This test identifies four serum proteins and seven red cell enzymes by gel electrophoresis. The proteins and enzymes are identified by their location on the gel at the end of the test. *Id.* at 594-99.

130. KIRBY, *supra* note 3, at 3.

131. *Id.*

132. See generally Thompson & Ford, *supra* note 14, at 51 n.36 (suggesting the difficulty of identifying an individual based on the ABO blood typing system when a significant percentage of the population has the same blood type). See also *supra* note 127 for the percentage frequencies of blood types in the Caucasian population.

133. KIRBY, *supra* note 3, at 3. In the DNA test, the more bands that match, the higher the probability that the samples came from the same source. For example, if ten bands match, the probability that an unrelated person has the same profile is one in 1,048,576. If eighteen bands match, the probability decreases to one in 68,719,475,200. *Id.* at 175. See *infra* notes 188-99 and accompanying text for a discussion of genetic principles that influence the probability calculations.

A second advantage is DNA durability.¹³⁴ DNA is relatively stable and can be collected from aged or weathered samples.¹³⁵ By comparison, HLA testing is considered reliable only on fresh blood.¹³⁶ Typing of red cell enzymes and serum proteins can be done on dried samples, but the reliability of the test is questioned when the samples are old or have been exposed to the weather.¹³⁷

A third advantage is that DNA testing can be performed on very small amounts of biological material.¹³⁸ One milliliter of fresh whole blood or a dime-sized dried stain usually will provide sufficient DNA for an RFLP analysis.¹³⁹ DNA from even smaller samples can be amplified and analyzed with the PCR test.¹⁴⁰

4. Problems and Criticisms

Although there are advantages to DNA identification analysis, there have been and continue to be questions about the scientific reliability and the appropriateness of the use of DNA in the legal setting.

The theory underlying DNA identification analysis is not at issue. The scientific and legal communities both accept that each person, except for identical twins, has a unique DNA.¹⁴¹ What is questioned, however, is the reliability of the analysis techniques used in forensic investigation and the validity of the data interpretation.

a. Analysis Techniques

Several potential problem areas have been identified in the analysis process. To begin with, there may not be enough DNA present in the sample or the DNA may be of poor quality.¹⁴² Although stable under many conditions, DNA will degrade¹⁴³ when exposed to prolonged

134. *Id.*

135. Hoeffel, *supra* note 4, at 469. DNA may be degraded by heat and moisture if exposed to these elements for too long a period of time. FORENSIC DNA ANALYSIS, *supra* note 45, at 7.

136. Thompson & Ford, *supra* note 14, at 51. Because white cells are fragile, many laboratories will only test blood samples that are received within 24 to 72 hours of being drawn. GIANNELLI & IMWINKELRIED, *supra* note 127, at 588.

137. Thompson & Ford, *supra* note 14, at 51. Critics also claim that red cell enzymes and serum proteins may be subject to aging effects that would cause the electrophoretic pattern to change. GIANNELLI & IMWINKELRIED, *supra* note 127, at 599.

138. Hoeffel, *supra* note 4 at 468-69.

139. KIRBY, *supra* note 3, at 51-52, 127. See also *supra* note 59 and accompanying text.

140. KIRBY, *supra* note 3, at 76.

141. Duceman, *supra* note 18, at 65.

142. See KIRBY, *supra* note 3, at 127; Thompson & Ford, *supra* note 14, at 65.

143. When DNA degrades, it breaks into smaller fragments. Degraded DNA is also known as low molecular weight DNA. Thompson & Ford, *supra* note 14, at 65.

sunlight or extensive soiling.¹⁴⁴ Degraded DNA samples, while easily identified in the laboratory,¹⁴⁵ cannot be used for an RFLP analysis.¹⁴⁶

Also, sample contamination can complicate test results.¹⁴⁷ Samples can be contaminated by foreign DNA, such as when there is co-mingling of suspect and victim blood,¹⁴⁸ or by chemical or bacterial agents derived from the sample environment or the testing process.¹⁴⁹ Some contaminants can be difficult to detect and may adversely affect test results.¹⁵⁰

PCR amplification analysis is particularly susceptible to contamination.¹⁵¹ Even the smallest trace of foreign DNA in the amplification process can produce a misidentification.¹⁵² Although the process of DNA purification should alleviate such contamination, there is no way to tell from the test results whether such contamination has or has not occurred.¹⁵³

Inconsistencies in testing conditions or procedures may also affect test results.¹⁵⁴ Criticism of testing reliability has led to the development of quality assurance standards¹⁵⁵ and the use of quality assurance programs by the testing laboratories.¹⁵⁶

Despite the potential for problems in the analysis process, there is a general consensus among scientists that DNA identification techniques

144. KIRBY, *supra* note 3, at 69-70.

145. An RFLP analysis of degraded DNA will produce a blank autoradiograph. Duceman, *supra* note 18, at 68-69.

146. Thompson & Ford, *supra* note 14, at 65-66.

147. Duceman, *supra* note 18, at 69-70.

148. Burk, *supra* note 12, at 464.

149. Thompson & Ford, *supra* note 14, at 66.

150. *Id.* at 92-96. Contaminants can inhibit the action of restriction enzymes in cleaving the DNA molecule or can bind to the DNA fragments during electrophoresis and affect fragment mobility. Either of these situations can result in a wrong band size on the autoradiograph. Duceman, *supra* note 18, at 70.

151. Thompson & Ford, *supra* note 14, at 77.

152. *Id.* at 77, 99. Foreign DNA in a sample can also undergo amplification during the PCR process, leading to false positive results. KIRBY, *supra* note 3, at 78-79.

153. Thompson & Ford, *supra* note 14, at 77.

154. *Id.* at 92-96. As one commentator states, "The quality of the final result can be no greater than the quality of the input DNA specimen and the attention of the analyst to assay details." KIRBY, *supra* note 3, at 91. *See also* DNA TECHNOLOGY, *supra* note 2, at 98 (stating that DNA analysis has a low inherent rate of false positive results, but that the error rate increases with poor laboratory practice).

155. Duceman, *supra* note 18, at 87. The Technical Working Group on DNA Analysis Methods (TWGDAM), coordinated by the FBI and composed of scientists from the United States and Canada, has established laboratory quality assurance guidelines for forensic DNA identification analysis. *Id.*

156. *Id.* at 66-67. *See also* DNA TECHNOLOGY, *supra* note 2, at 99-101 (setting out principles of quality assurance and regulation for the laboratories and personnel that conduct forensic DNA identification analysis).

produce reliable results.¹⁵⁷ According to a report published by the Office of Technology Assessment, "forensic uses of DNA tests are both reliable and valid when properly performed and analyzed by skilled personnel."¹⁵⁸

Most courts also have found DNA identification analysis techniques to be reliable and to have general acceptance in the scientific community.¹⁵⁹ In those few instances where courts have excluded DNA evidence because of questions of testing reliability, most of the exclusions were based on factors that were unique to the particular testing situation.¹⁶⁰

b. Data Interpretation

There are two areas of controversy relating to the interpretation of data generated by forensic DNA identification analysis. The first area of controversy involves the interpretation of the autoradiograph. The second concerns the assumptions on which the band frequency calculations are based.

i. Autoradiograph Interpretation

Determining whether there is a match between the DNA band sample of the suspect and that obtained from the crime scene can be difficult.¹⁶¹ The bands produced by the RFLP analysis may be faint,

157. FORENSIC DNA ANALYSIS, *supra* note 45, at 17. This agreement does not extend to the science surrounding the calculation of the statistical probabilities. See *infra* notes 188-99 and accompanying text for an explanation of the problems surrounding the calculation of statistical probabilities.

158. *Id.* at 17-18. (quoting OFFICE OF TECHNOLOGY ASSESSMENT, U.S. CONGRESS, GENETIC WITNESS: FORENSIC USES OF DNA TESTS 7-8 (1990)).

159. See, e.g., *U.S. v. Martinez*, 3 F.3d 1191, 1197 (8th Cir. 1993) (stating that future courts can take judicial notice of the reliability of the general theory and techniques of DNA profiling); *Fishback v. People*, 851 P.2d 884, 893 (Colo. 1993) (finding DNA identification theory and technique generally accepted in the relevant scientific community); *Caldwell v. State*, 393 S.E.2d 436, 441 (Ga. 1990) (finding DNA identification techniques were based on sound scientific theory); *State v. Futch*, 860 P.2d 264, 270 (Or. Ct. App. 1993) (concluding that forensic DNA testing has sufficient scientific reliability to have probative value); *People v. Watson*, 629 N.E.2d 634, 643 (Ill. App. Ct. 1994) (finding that the RFLP technique is capable of reliably discerning matches across multiple loci).

160. *Duceman*, *supra* note 18, at 67-68. See, e.g., *State v. Schwartz*, 447 N.W.2d 422, 428 (Minn. 1989) (finding test results inadmissible because laboratory did not comport with appropriate standards and controls); *People v. Castro*, 545 N.Y.S.2d 985, 997-98 (Sup. Ct. 1989) (finding evidence inadmissible because testing laboratory failed to perform accepted scientific techniques). *But see* *People v. Keene*, 591 N.Y.S.2d 733, 740 (Sup. Ct. 1992) (finding evidence not admissible because a procedure used by laboratory was not generally accepted by relevant scientific community).

161. *Duceman*, *supra* note 18, at 80.

blurred, or too intense for straightforward analysis.¹⁶² Also, there currently are no uniform laboratory standards for defining a match.¹⁶³

In addition, visual matching is a subjective process and may be susceptible to bias.¹⁶⁴ The DNA analyst has detailed knowledge of the case, and this knowledge could influence the match decision.¹⁶⁵ For this reason, most quality assurance guidelines now require that autoradiographs be independently reviewed by two examiners and that both examiners reach the same conclusion.¹⁶⁶

ii. Frequency Calculations

Once a match has been found, the probability that the matched samples have come from the same person must be determined.¹⁶⁷ This probability depends on two factors: first, the number of bands the two prints have in common, and second, the frequency with which the bands appear in the relevant population.¹⁶⁸

The number of bands produced in a DNA identification analysis is determined by the number of probes used.¹⁶⁹ An RFLP analysis currently uses four or more probes,¹⁷⁰ each of which produces one or two bands.¹⁷¹ A probability¹⁷² is calculated for each band produced in the analysis, and the probabilities are then multiplied together.¹⁷³ The more bands that match, the higher the likelihood that the samples came from the same person.¹⁷⁴

But even if all bands match, it does not necessarily prove that the samples are from a common source. If everyone in the population has

162. *Id.* at 76; see also Hoeffel, *supra* note 4, at 474.

163. Hansen, *supra* note 45, at 222. Each laboratory maintains its own criteria for determining a match. Lifecodes, for example, finds a match if the variation in band size does not exceed plus or minus 1.8%. Duceman, *supra* note 18, at 80-81. The FBI declares a match if the variation is within plus or minus 2.5%. *Id.* See also DNA TECHNOLOGY, *supra* note 2, at 54 (stating that there must be "objective, precise, and uniformly applied" matching rules for valid identification).

164. Duceman, *supra* note 18, at 81-82.

165. *Id.* at 82.

166. *Id.*

167. KIRBY, *supra* note 3, at 172.

168. Thompson & Ford, *supra* note 14, at 81.

169. See *supra* notes 85-94 and accompanying text.

170. KIRBY, *supra* note 3, at 141.

171. Thompson & Ford, *supra* note 14, at 72.

172. A probability is a numerical value between zero and one that indicates the likelihood that an event will or will not occur. KIRBY, *supra* note 3, at 164. In forensic DNA analysis, probability refers to the likelihood that matching suspect and crime samples have the same source. *Id.*

173. Duceman, *supra* note 18, at 83.

174. For example, if the odds for a coincidental match were one in ten for each band, a coincidental match at one band would occur once in ten individuals. A coincidental match at four bands would occur once in 10,000 ($1/10 \times 1/10 \times 1/10 \times 1/10$) individuals.

the same allele, or polymorphic gene, a match means nothing. The DNA print could have come from anyone in the population.¹⁷⁵ In order to give meaning to a match, therefore, it is necessary to know the frequency with which each band occurs in the population.¹⁷⁶

To determine the frequency, forensic scientists use probabilistic¹⁷⁷ and statistical¹⁷⁸ calculations.¹⁷⁹ To begin, a probability estimate is assigned to each band produced by the DNA analysis.¹⁸⁰ These estimates are derived from databases containing DNA profiles obtained by using the same probes on other individuals in a specific population.¹⁸¹ Because a particular racial group may have more bands in common than would the general population, these databases are segregated by race.¹⁸²

Once a probability estimate has been assigned to each band, the probabilities are multiplied together.¹⁸³ The reciprocal of the product of the probabilities is the chance that a match between suspect and crime scene DNA profiles is coincidental.¹⁸⁴ The accuracy of this calculation depends entirely on the accuracy of the frequency estimates found in the databases.¹⁸⁵ And these frequency estimates are the source of the strongest criticisms of forensic DNA identification analysis.¹⁸⁶

The controversy focuses on the population samples used for the various databases.¹⁸⁷ Some critics maintain that the sample populations

175. KIRBY, *supra* note 3, at 172.

176. *Id.*

177. See *supra* note 172.

178. The purpose of statistics is to infer something about a population based on observations taken from a sample of that population. KIRBY, *supra* note 3, at 153.

179. *Id.* at 149.

180. Duceaman, *supra* note 18, at 83.

181. Hoeffel, *supra* note 4, at 474. A population is a collection of individuals that have certain features in common, such as all Asians living in the United States. KIRBY, *supra* note 3, at 150. Natural populations are often characterized by differences in allele frequencies. *Id.* at 154. For example, the Group B blood type is more common in Asia than in Western Europe, and the Group A and B blood types are rarely found in Native Americans. *Id.* at 25.

182. Duceaman, *supra* note 18, at 84-85. Classifications usually include Caucasians, Blacks, Asians, and Hispanics. *Id.* at 84.

183. Duceaman, *supra* note 18, at 83. The multiplication step is known as the product rule. The probabilities can be multiplied together only if the frequencies have been derived from a population that is freely mixing (biologically unrelated) and if the alleles identified by the probes are inherited independently of each other. See generally Thompson & Ford, *supra* note 14, at 81-85. See also *infra* notes 191-98 and accompanying text.

184. Duceaman, *supra* note 18, at 83. For example, if the product of each probe's probabilities is one in 250,000 individuals, then there is a 250,000 to one chance that the match between the suspect and the crime scene is coincidental.

185. *Id.* at 83-84.

186. *Id.*

187. *Id.*

used to compile the databases are too small or are not truly representative of the relevant populations.¹⁸⁸ Others argue that the racial categories used in the databases are too broad;¹⁸⁹ that there is more diversity within races than between them. Therefore, the races should be further divided into subgroups that better reflect ethnic, religious, and geographic similarities.¹⁹⁰

The formula used to calculate the frequency with which a band will occur in a population is based on the assumption that the sample population is freely mixing.¹⁹¹ If the population is not freely mixing, population substructure can occur.¹⁹² With population substructure, subgroups within the population will have more alleles or more combinations of alleles in common than would the population at large.¹⁹³ Any population substructure within the sample population, therefore, will affect the accuracy of the frequency calculations.¹⁹⁴

The use of the product rule, by which the probabilities for each band are multiplied together, requires that the represented alleles not

188. *Id.* at 84. A sample population that is too small or not truly representative could result in misleading probability values, especially for rare alleles. *Id.*

189. Duceman, *supra* note 18 at 84.

190. *Id.* (noting that the Hispanic designation, for example, might include Mexicans, Puerto Ricans, or Cubans, each of which has a different mixture of Indian, Spanish, or African ancestry).

191. *Id.* A population that is freely mixing is said to be in Hardy-Weinberg equilibrium. The Hardy-Weinberg law states that in a large random-mating population that is not subject to such outside influences as mutation, migration, or selection, gene frequencies will remain constant over time. Any non-random mating (inbreeding) and migration can upset this equilibrium. KIRBY, *supra* note 3, at 168-69.

192. Duceman, *supra* note 18, at 85. See also DNA TECHNOLOGY, *supra* note 2, at 80-82 (suggesting methods for determining the possibility of population substructure).

193. Hoeffel, *supra* note 4, at 490.

194. See *id.* Testing samples of the population at large would not, therefore, provide an accurate indication of the allele frequencies for the subgroup. For example, suppose Hispanics living in a certain geographical area have an allele frequency of one in 2500. It is later found, however, that Hispanics of Cuban descent living in that area have a frequency of one in 240 for the same allele. The Hispanic frequency calculation, therefore, would not reflect the frequency of the allele in the Cuban Hispanic population.

The National Research Council (NRC) proposed the "ceiling principle" as a practical and sound approach for accounting for possible population substructure. DNA TECHNOLOGY, *supra* note 2, at 82. The NRC ceiling principle determines an upper bound frequency for each allele that is not based on ethnic background. For example, if a particular allele occurs in four percent of one population, the "ceiling" frequency for that allele would be set at 15% in all populations. These ceiling frequencies could then be multiplied together using the product rule. *Id.* at 83. The use of ceiling frequencies will result in a more conservative match estimate. See, e.g., Caldwell v. State, 393 S.E.2d 436, 444 (Ga. 1990) (using a similar calculation method that reduced the original frequency of one in 24 million to one to 250,000).

The NRC noted that the conservative approach "imposes no fundamental limitation on the power of the technique." DNA TECHNOLOGY, *supra* note 2, at 82.

be linked.¹⁹⁵ Alleles that are located in close proximity to each other on a chromosome are usually inherited together and, therefore, are said to be linked.¹⁹⁶ The presence of population substructure can result in linkage disequilibrium.¹⁹⁷ Such linkage disequilibrium would invalidate the use of the product rule.¹⁹⁸ The potential for population substructure in the reference databases has been described as "the most hotly-contested issue in DNA litigation today."¹⁹⁹

The controversy has affected both the scientific community²⁰⁰ and the courts. Several state appellate courts have refused to admit DNA evidence on the ground that the probability estimates are not reliable.²⁰¹ Other state courts have admitted evidence of a match, but would not admit the probability estimates.²⁰²

III. DNA EVIDENCE IN THE COURTROOM

As with any new scientific theory, DNA identification analysis must satisfy an admissibility test in each jurisdiction before receiving judicial acceptance. Courts generally use one of two tests. The first, the *Frye*

195. Duceman, *supra* note 18, at 86.

196. KIRBY, *supra* note 3, at 19.

197. Duceman, *supra* note 18, at 86. Linkage disequilibrium occurs when an allele at one locus is linked to an allele at another locus on the same chromosome with a greater frequency than would be expected by chance. KIRBY, *supra* note 3, at 334.

198. Duceman, *supra* note 18, at 86. For example, if alleles A and B are not linked, and allele A occurs in one of every 2500 individuals and allele B in one of every 400 individuals, the possibility of two individuals having both alleles A and B is one in a million ($1/2500 \times 1/400$). If the two alleles are linked, the two frequency probabilities cannot be multiplied together because both alleles occur at the same frequency in a given individual.

199. Duceman, *supra* note 18, at 85 (quoting Harlan A. Levy, *DNA: Race, Ethnicity and Statistical Evidence*, N.Y. L.J., July 15, 1991, at 1).

200. For more information on the scientific controversy, see Richard C. Lewontin & Daniel L. Hartl, *Population Genetics in Forensic DNA Typing*, 254 *Sci.* 1745 (1991) (attacking reliability of DNA statistical analysis) and Ranajit Chakraborty & Kenneth K. Kidd, *The Utility of DNA Typing in Forensic Work*, 254 *Sci.* 1735 (1991) (defending reliability of DNA statistical analysis). See also DNA TECHNOLOGY, *supra* note 2, at 80 (describing the controversy and the NRC's proposed compromise).

201. See, e.g., *People v. Barney*, 10 Cal. Rptr.2d 731, 744 (Ct. App. 1992) (citing scientific debate as indisputable evidence that there is no general acceptance of statistical calculation process); *State v. Pennell*, 584 A.2d 513, 519 (Del. Super. Ct. 1989) (concluding that statistical probabilities have not been demonstrated to be sufficiently reliable); *Commonwealth v. Curnin*, 565 N.E.2d 440, 442 (Mass. 1991) (concluding that there was no demonstrated general acceptance of probability calculations).

202. See, e.g., *State v. Bible*, 858 P.2d 1152, 1193 (Ariz. 1993) (concluding that there is no general acceptance in relevant scientific community for the laboratory's random match probability calculations); *State v. Vandebogart*, 616 A.2d 483, 494 (N.H. 1992) (finding FBI's method for estimating population frequencies has not found general acceptance in field of population genetics); *Commonwealth v. Crews*, 640 A.2d 395, 402 (Pa. 1994) (finding statistical analysis has not achieved widespread acceptance in scientific community).

test,²⁰³ or one of its variations,²⁰⁴ is used in a majority of jurisdictions.²⁰⁵ Under the *Frye* test, a novel scientific technique must be accepted by the relevant scientific community before it will be admitted by the court.²⁰⁶ The second test follows the basic relevancy standard of the Federal Rules of Evidence²⁰⁷ and is used in a minority of jurisdictions.²⁰⁸ For admissibility under the Federal Rules, such evidence must have some relevance to the issues in the case,²⁰⁹ and the probative value must outweigh the potential for prejudice.²¹⁰

A. *The Frye Test*

1. *Background*

In 1923, James Alphonso Frye appealed his second degree murder conviction on the ground that the trial court erred in refusing to allow expert testimony on the results of a systolic blood pressure deception test.²¹¹ The *Frye* court developed the following admissibility standard:

Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define.

203. The *Frye* test originated in *Frye v. United States*, 293 F. 1013, 1014 (D.C. Cir. 1923).

204. See *infra* Part III.A for a description of the *Frye* test and *Frye* test variations.

205. Of the 38 jurisdictions that have decided the issue of forensic DNA evidence admissibility, 26 use the *Frye* test or one of its variations. See *infra* note 228 and part III.A.3 for the states that use the *Frye* test or one of its variations. The federal circuits no longer use the *Frye* test in determining DNA admissibility. See *infra* Part III.D for a discussion of the federal standard.

206. *Frye*, 293 F. at 1014.

207. Under this standard, Rules 401, 402, 403, and 702 of the Federal Rules of Evidence are used to determine the admissibility of DNA evidence.

Rule 401: "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.

Rule 402: 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.

Rule 403: 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.

Rule 702: 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. 401, 402, 403, 702.

208. Three federal circuits and 12 states use the relevancy standard under the Federal Rules of Evidence to determine the admissibility of forensic DNA evidence. See *infra* notes 250 and 252.

209. See FED. R. EVID. 401, 402, 702.

210. FED. R. EVID. 403.

211. *Frye v. United States*, 293 F. 1013, 1013-14 (D.C. Cir. 1923).

Somewhere in this twilight zone the evidential force of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, *the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs.*²¹²

The court went on to find that the systolic blood pressure deception test did not have sufficient recognition in the relevant scientific field to justify admitting the test results into evidence.²¹³

2. Application to DNA Evidence

When the *Frye* test was first applied to DNA evidence, three questions challenged the courts.²¹⁴ The courts first had to decide which scientific fields were relevant to the acceptance of DNA evidence.²¹⁵ Ultimately, the fields were found to include molecular biology, genetics, and population genetics.²¹⁶ Statistics and forensic science were also considered to be applicable.²¹⁷

The second question involved the scope of general acceptance. The question was whether the standard required acceptance of both the underlying theories of DNA and the techniques involved in DNA analysis.²¹⁸ Most courts, when first applying the *Frye* test to DNA evidence, required a general acceptance of both theories and techniques.²¹⁹

The third question for the courts to decide was the meaning of general acceptance.²²⁰ One court noted that "the test is not whether a particular procedure is unanimously endorsed by the scientific community, but whether it is generally acceptable as reliable."²²¹ Another court has held that the evidence must be accepted by a clear majority

212. *Id.* at 1014 (emphasis added).

213. *Id.*

214. See Kenneth E. Melson, *Legal and Ethical Considerations*, in KIRBY, *supra* note 3, at 189, 193-95.

215. *Id.* at 193.

216. *Id.* See, e.g., *People v. Wesley*, 533 N.Y.S.2d 643, 645, 659 (Albany County Ct. 1988), *aff'd*, 589 N.Y.S.2d 197 (App. Div. 1992).

217. Thompson & Ford, *supra* note 14, at 56-57.

218. Melson, *supra* note 214, at 194.

219. *Id.* See, e.g., *Ex parte Perry*, 586 So. 2d 242, 250 (Ala. 1991) (holding that there must be an examination of whether the theory and the current techniques used are generally accepted and whether those techniques were properly followed in a particular case); *Polk v. State*, 612 So. 2d 381, 390 (Miss. 1992) (admitting DNA evidence where there was a generally accepted theory and technique and the testing laboratory used those techniques properly); *People v. Castro*, 545 N.Y.S.2d 985, 987 (Sup. Ct. 1989). According to the *Castro* court, the complexity of the DNA tests and the powerful impact such tests had on the jury required that the testing procedures used in a particular case undergo a preliminary critical examination. *Id.*

220. Melson, *supra* note 214, at 194-95.

221. *Castro*, 545 N.Y.S.2d at 986-87.

of the scientific community.²²² The Minnesota Supreme Court requires that "experts in the field generally agree that the evidence is reliable and trustworthy."²²³

Once the courts decided how to define general acceptance, they had to determine whether or not the theory and techniques relating to DNA evidence met the standard. In making this determination, the courts relied on expert testimony, scientific and legal writings, and judicial opinions.²²⁴ Virtually all courts that apply the *Frye* test or one of its variations to determine admissibility of forensic DNA evidence have found both the DNA theory and the analysis techniques accepted by the relevant scientific community.²²⁵ Not all courts, however, have reached similar acceptance for the theories and procedures that underlie DNA data interpretation.²²⁶

3. Variations of the *Frye* Test

Only a minority of courts use a strict *Frye*²²⁷ test.²²⁸ Many courts that follow the *Frye* standard have created *Frye* hybrids by adopting addi-

222. *State v. Anderson*, 853 P.2d 135, 138-39 (N.M. Ct. App.), *cert. granted*, 848 P.2d 531 (N.M. 1993).

223. *State v. Schwartz*, 447 N.W.2d 422, 424 (Minn. 1989).

224. *State v. Williams*, 599 A.2d 960, 964 (N.J. Super. Ct. 1991).

225. *See, e.g., Williams*, 599 A.2d at 968 (concluding that PCR testing has gained general acceptance); *State v. Cauthron*, 846 P.2d 502, 511 (Wash. 1993) (affirming the general acceptance of the scientific principle and the RFLP method of DNA typing).

226. *See, e.g., State v. Bible*, 858 P.2d 1152, 1193 (Ariz. 1993) (concluding that there is no general acceptance in the relevant scientific community for Cellmark's random match probability calculations); *People v. Barney*, 10 Cal. Rptr. 2d 731, 744 (Ct. App. 1992) (finding scientific debate demonstrates indisputably that there is no general acceptance of statistical calculation process); *Commonwealth v. Curnin*, 565 N.E.2d 440, 442 (Mass. 1991) (concluding there was no demonstrated general acceptance of Cellmark's probability calculations); *State v. Vandebogart*, 616 A.2d 483, 494 (N.H. 1992) (finding FBI's method for estimating population frequencies has not gained general acceptance in the field of human population genetics).

227. The strict *Frye* test is also known as the "pure *Frye*" test. Stephanie B. Goldberg, *A New Day for DNA?* 78 A.B.A. J. Apr. 1992, at 84.

228. Determining exactly which jurisdictions follow the "pure-*Frye*" standard is difficult. Often a court will state that it follows the *Frye* test but then goes on to define additional criteria for admissibility. The following jurisdictions appear to follow a "pure-*Frye*" test: Colorado, *Fishback v. People*, 851 P.2d 884, 889 (Colo. 1993); District of Columbia, *United States v. Porter*, 618 A.2d 629, 633 (D.C. 1992); Kentucky, *Harris v. Commonwealth*, 846 S.W.2d 678, 681 (Ky. 1992); Maryland, *Cobey v. State*, 559 A.2d 391, 392 (Md. Ct. Spec. App.), *cert. denied*, 565 A.2d 670 (Md. 1989); Michigan, *People v. Adams*, 489 N.W.2d 192, 194 (Mich. Ct. App. 1992), *modified in part and cert. denied in part*, 497 N.W.2d 182 (Mich. 1993); Missouri, *State v. Davis*, 814 S.W.2d 593, 600 (Mo. 1991), *cert. denied*, 112 S. Ct. 911 (1992); New Mexico, *State v. Anderson*, 853 P.2d 135, 137 (N.M. Ct. App.), *cert. granted*, 848 P.2d 531 (N.M. 1993).

Florida, which previously admitted DNA evidence under the relevancy test, now applies the *Frye* test. *See Vargas v. State*, Nos. 92-556, 92-557, 1994 WL 231360, at *5 (Fla. Dist. Ct. App. June 1, 1994) (citing *Flanagan v. State*, 625 So. 2d 827 (Fla. 1993)).

tional requirements for admissibility. The most popular of the *Frye* hybrids, or “*Frye-plus*”²²⁹ tests, is a test developed in *People v. Castro*.²³⁰

a. *The Frye-Castro Test*

According to the court in *Castro*,²³¹ an “important flaw in the *Frye* test is that by focusing attention on the general acceptance issue, the test obscures critical problems in the use of the particular technique.”²³² The court went on to advance a three-prong analysis that requires an acceptance of both the DNA theory and technique and that the test be performed in accordance with accepted scientific techniques.²³³

Some courts require that all three prongs be satisfied before novel scientific evidence is admissible.²³⁴ Others find that the third prong goes to the weight of the evidence not to its admissibility.²³⁵ The ma-

229. Goldberg, *supra* note 227, at 84.

230. 545 N.Y.S.2d 985, 987 (Sup. Ct. 1989). Other cases that follow *Castro* include, *Ex parte Perry*, 586 So. 2d 242, 250 (Ala. 1991); *Hopkins v. State*, 579 N.E.2d 1297, 1302 (Ind. 1991); *Polk v. State*, 612 So. 2d 381, 390 (Miss. 1992); *State v. Vandebogart*, 616 A.2d 483, 490 (N.H. 1992); *People v. Mohit*, 579 N.Y.S.2d 990, 992 (Westchester Cnty. Ct. 1992); *People v. Keene*, 591 N.Y.S.2d 733, 735 (Sup. Ct. 1992); *Commonwealth v. Rodgers*, 605 A.2d 1228, 1235-36 (Pa. Super. Ct.), *appeal denied*, 615 A.2d 1311 (Pa. 1992).

231. *Castro*, 545 N.Y.S.2d at 985.

232. *Id.* at 987 (quoting GIANNELLI & IMWINKELRIED, *supra* note 127, at 1226).

233. The court’s three prong analysis is as follows:

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

Id. at 987.

According to the court, the third prong determination should be made at a pre-trial hearing based on expert testimony. *Id.* at 998-99.

234. See, e.g., *Ex parte Perry*, 586 So. 2d 242, 250 (Ala. 1991). The *Perry* court separated the admissibility of DNA evidence into two areas: (1) DNA “matching” evidence, and (2) DNA population frequency evidence. The court remanded to the trial court with instructions to apply the three prongs to both the matching evidence and the population frequency evidence. See also *Polk v. State*, 612 So. 2d 381, 390-93 (Miss. 1992) (finding that all three prongs were met for admission of evidence of a DNA match); *People v. Castro*, 545 N.Y.S.2d 985, 989, 995, 997 (Sup. Ct. 1989) (finding that DNA matching evidence satisfied the first two prongs but not the third because the laboratory failed to use generally accepted scientific techniques).

235. See, e.g., *State v. Vandebogart*, 616 A.2d 483, 492-94 (N.H. 1992) (holding that the first prong was satisfied and that the second was satisfied as to the RFLP analysis but not as to the frequency calculations).

majority of courts using the *Frye-Castro* test have concluded that DNA evidence is admissible.²³⁶

b. Other Variations

Another *Frye*-hybrid test was set forth in *United States v. Two Bulls*.²³⁷ In remanding the case for an expanded pretrial hearing on the admissibility of the DNA evidence, the Eighth Circuit Court of Appeals instructed the trial court to decide, in addition to the acceptability of the testing procedures, whether the evidence was more prejudicial than probative.²³⁸

Other variations of the *Frye* test have been used to determine admissibility of forensic DNA evidence. Several courts combine the *Frye* test with the relevancy test.²³⁹ These courts focus on the probative and

236. See, e.g., *Perry v. State*, 606 So. 2d 224, 226 (Ala. Crim. App. 1992) (finding DNA evidence was properly admitted); *Hopkins v. State*, 579 N.E.2d 1297, 1304 (Ind. 1991) (holding that the trial court did not err in admitting evidence of forensic DNA test results); *Polk v. State*, 612 So. 2d 381, 393 (Miss. 1992) (finding matching evidence admissible); *People v. Mohit*, 579 N.Y.S.2d 990, 999 (Westchester County Ct. 1992) (finding DNA evidence admissible but limiting prosecution to the most conservative frequency estimate); *Commonwealth v. Rodgers*, 605 A.2d 1228, 1236 (Pa. Super. Ct.) (finding DNA evidence admissible), *appeal denied*, 615 A.2d 1311 (Pa. 1992). But see *Vargas v. State*, Nos. 92-556, 92-557, 1994 WL 231360, at *13 (Fla. Dist. Ct. App. June 1, 1994) (concluding that method used to arrive at population frequencies is not generally accepted in the relevant scientific community); *Vandebogart*, 616 A.2d at 494 (finding FBI's method of estimating population frequencies has not found general acceptance in field of population genetics); *People v. Keene*, 591 N.Y.S.2d 733, 740 (Sup. Ct. 1992) (finding procedure used by testing laboratory was not generally accepted in molecular genetics community); *Commonwealth v. Crews*, 640 A.2d 395, 402 (Pa. 1994) (finding that statistical analysis has not achieved widespread acceptance in the scientific community).

237. 918 F.2d 56, 61 (8th Cir. 1990), *vacated, reh'g granted, dismissed as moot*, 925 F.2d 1127 (8th Cir. 1991). The *Two Bulls* test is not binding on federal courts. *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 113 S. Ct. 2786, 2794 (1993) (holding that the *Frye* standard no longer applies to the admissibility of novel scientific evidence in the federal courts).

238. *Id.* at 61. The test outlined by the court of appeals included five steps: (1) whether DNA evidence is generally accepted by the scientific community; (2) whether the testing procedures are generally accepted as reliable if performed properly; (3) whether the test was performed properly; (4) whether the evidence is more prejudicial than probative; and (5) whether the statistics used to determine the probability of someone else having the same genetic characteristics is more probative than prejudicial under Rule 403 of the Federal Rules of Evidence. *Id.* See also *Ex parte Perry*, 586 So. 2d 242, 254 (Ala. 1991) (finding that if prejudicial impact of evidence outweighs its probative value, evidence is not admissible); *State v. Houser*, 490 N.W.2d 168, 184 (Neb. 1992) (combining the tests found in *Castro* and *Two Bulls*).

239. See, e.g., *State v. Montalbo*, 828 P.2d 1274, 1280-81 (Haw. 1992) (admissibility is based on general acceptance in relevant scientific community together with five relevancy factors); *Smith v. Deppish*, 807 P.2d 144, 159 (Kan. 1991) (finding that even if admissible under *Frye*, test results may be inadmissible on grounds of relevancy); *Commonwealth v. Curnin*, 565 N.E.2d 440, 443 n.8 (Mass. 1991) (finding that relevant evi-

prejudicial aspects of the evidence, in addition to general acceptance in the relevant scientific community.²⁴⁰ Some courts find the reliability of test results is crucial.²⁴¹ These courts focus on the accuracy of these test results.²⁴² Still other courts emphasize the importance of the testifying expert's qualifications.²⁴³

B. *The Relevancy Test*

An alternative test for admissibility of new scientific evidence is the relevancy test. Based on the Federal Rules of Evidence, "the relevancy standard balances the probativeness, materiality, and reliability of the evidence against the risk of misleading or confusing the jury or unfairly prejudicing the defendant."²⁴⁴

Under the Federal Rules of Evidence, admissibility of novel scientific evidence can be admitted after: (1) determining the probative value of the evidence;²⁴⁵ (2) identifying possible dangers, such as a prejudicial effect on the jury;²⁴⁶ and (3) balancing the probative value against any identified dangers.²⁴⁷ The evidence is relevant if the trier of fact will be assisted in understanding the evidence or in determining a fact in issue.²⁴⁸ The reliability of the theory or technique is incorporated into the probative step because the probative value of the evidence depends on the reliability of the technique or the theory.²⁴⁹

dence could be admissible even if no general acceptance of process); *State v. Wimberly*, 467 N.W.2d 499, 506 (S.D. 1991) (finding that issues pertaining to relevancy may be raised); *State v. Woodall*, 385 S.E.2d 253, 260 (W.Va. 1989) (finding that evidence may be found inadmissible under West Virginia Rules of Evidence 401, 403, or 702).

240. See *infra* part III.B for further discussion of the relevancy test.

241. *State v. Schwartz*, 447 N.W.2d 422, 426 (Minn. 1989). See also *People v. Lipscomb*, 574 N.E.2d 1345, 1356 (Ill. App. Ct.), (finding that once *Frye* is met, the issue becomes whether the procedures used are reliable), *appeal denied*, 580 N.E.2d 127 (Ill. 1991); *State v. Williams*, 599 A.2d 960, 964 (N.J. Super. Ct. 1991) (listing eight factors which are relevant to determining reliability).

242. See, e.g., *Schwartz*, 447 N.W.2d at 426.

243. See, e.g., *State v. Bible*, 858 P.2d 1152, 1184 (Ariz. 1993) (finding that once *Frye* is satisfied, necessary foundation includes expert's qualifications, proper application of testing techniques, and accurate recording of test results); *People v. Axell*, 1 Cal. Rptr. 2d 411, 421 (Ct. App. 1991) (combining reliability of method, correct scientific procedures, and proper qualification of expert); *State v. Cauthron*, 846 P.2d 502, 507 (Wash. 1993) (finding expert testimony is admissible only when the underlying scientific principle satisfies *Frye*, the witness qualifies as an expert, and testimony is helpful to the trier of fact).

244. *State v. Pierce*, 597 N.E.2d 107, 112 (Ohio 1992) (quoting Case Note, Lorie A. Robinson, *United States v. Two Bulls: Eighth Circuit Addresses Admissibility of Forensic DNA Evidence*, 37 LOY. L.REV. 173, 177 (1991)).

245. FED. R. EVID. 401.

246. FED. R. EVID. 403.

247. *Id.*; see also *Pierce*, 597 N.E.2d at 112.

248. FED. R. EVID. 702. See also *United States v. Jakobetz*, 955 F.2d 786, 796 (2d Cir.), *cert. denied*, 113 S. Ct. 104 (1992); *Pierce*, 597 N.E.2d at 112.

249. See *United States v. Downing*, 753 F.2d 1224, 1226, 1231 (3d Cir. 1985).

Jurisdictions rely on either a "pure relevancy" standard²⁵⁰ or a "relevancy-plus" standard.²⁵¹ The relevancy-plus standard incorporates the *Frye* test or other requirements into the traditional relevancy standard.²⁵²

One "relevancy-plus" standard incorporates a reliability requirement. In *United States v. Jakobetz*,²⁵³ the Second Circuit Court of Appeals stated that the threshold question should be whether the data being offered is reliable.²⁵⁴ Included in that showing would be an indication of how the laboratory work was done and the analysis and assumptions underlying the probability calculations.²⁵⁵

Another "relevancy-plus" standard is found in *State v. Pennell*.²⁵⁶ In *Pennell* the Delaware Superior Court set forth a five-step analysis to be used in determining whether expert testimony on DNA evidence is admissible.²⁵⁷

250. The following jurisdictions apply a "pure relevancy" approach in determining the admissibility of DNA evidence: Arkansas, *Prater v. State*, 820 S.W.2d 429, 436 (Ark. 1991); Iowa, *State v. Brown*, 470 N.W.2d 30, 32 (Iowa 1991); Louisiana, *State v. Quatrevingt*, 617 So. 2d 484, 490 (La. Ct. App. 1992); Ohio, *State v. Pierce*, 597 N.E.2d 107, 112 (Ohio 1992); Oregon, *State v. Futch*, 860 P.2d 264, 270 (Or. Ct. App. 1993); Texas, *Kelly v. State*, 824 S.W.2d 568, 573 (Tex. Crim. App. 1992); Wyoming, *Rivera v. State*, 840 P.2d 933, 941-42 (Wyo. 1992).

251. Goldberg, *supra* note 227, at 84.

252. Jurisdictions following a "relevancy-plus" approach in determining the admissibility of DNA evidence are: Second Circuit, *United States v. Jakobetz*, 955 F.2d 786, 796-97 (2d Cir.), *cert. denied*, 113 S. Ct. 104 (1992); Delaware, *State v. Pennell*, 584 A.2d 513, 515 (Del. Super. Ct. 1989).

253. 955 F.2d 786 (2d Cir.), *cert. denied*, 113 S. Ct. 104 (1992).

254. *Id.* at 799-800.

255. *Id.* The trial court considered nine factors in its determination that the evidence was admissible:

- (1) the experts' qualifications and stature; (2) the existence of specialized literature; (3) the novelty of the technique and its relationship to more established areas of scientific analysis; (4) whether the technique has been generally accepted by experts in the field; (5) the nature and breadth of the inference adduced; (6) the clarity with which the technique may be explained; (7) the extent to which basic data may be verified by court and jury; (8) the availability of other experts to evaluate the technique; and (9) the probative significance of the evidence.

Id. at 797-98.

256. 584 A.2d 513, 515 (Del. Super. Ct. 1989).

257. *Id.* The five steps derived from Rule 403 of the Delaware Rules of Evidence, are:

- (1) whether the expert is qualified; (2) whether the evidence offered is admissible, relevant, and reliable; (3) whether the bases for the expert's opinion are those reasonably relied on by experts in the field; (4) whether the specialized knowledge will assist the trier-of-fact to understand the evidence and determine a fact in issue; and (5) whether such evidence would create unfair prejudice, confusion of the issues, or mislead the jury.

Id.

The *Pennell* court found that the tests and procedures used to produce matching DNA samples met the five requirements. However, the court also found that the statisti-

C. *The Reliability Test*

Several courts apply an admissibility test that is not based on either the *Frye* or the relevancy standard. The Georgia Supreme Court requires that the trial judge decide whether the procedure or technique has reached a scientific state of "verifiable certainty."²⁵⁸ This determination may be based on evidence presented at trial through expert testimony or exhibits, treatises, or the rationale of cases in other jurisdictions.²⁵⁹

The supreme courts in North Carolina²⁶⁰ and Virginia²⁶¹ apply a reliability test. The North Carolina court bases its reliability determination on the qualifications of the expert.²⁶² In contrast, the Virginia Supreme Court holds that DNA evidence is admissible if the scientific technique is reliable and the testing is properly conducted.²⁶³

D. *The Daubert Test*

In *Daubert v. Merrell Dow Pharmaceuticals, Inc.*,²⁶⁴ the United States Supreme Court redefined the admissibility standard for scientific expert testimony. The Supreme Court ruled that the Federal Rules of Evidence have replaced the *Frye* test.²⁶⁵ The Court held that the "austere" general acceptance standard of *Frye*, was "absent from and incompatible with the Federal Rules of Evidence [and] should not be applied in federal trials."²⁶⁶

The Court went on to define the new federal standard. "[U]nder the Rules, the trial judge must ensure that any and all scientific testimony

cal probabilities failed to meet the second step's reliability requirement. Without the measure of scientific certainty, the potential prejudicial effects of the frequency probabilities clearly outweighed their probative value. *Id.* at 522.

258. *Caldwell v. State*, 393 S.E.2d 436, 441 (Ga. 1990). The test examines whether the scientific principles and techniques are valid and capable of producing reliable results and whether the procedures were performed in a scientifically acceptable manner. *Id.*

259. *Id.* Applying the test, the *Caldwell* court found the match results were admissible but the population statistics were not because the State failed to establish that the database populations were in Hardy-Weinberg equilibrium. *Id.* at 442, 444.

260. *State v. Pennington*, 393 S.E.2d 847, 852-53 (N.C. 1990).

261. *Spencer v. Commonwealth*, 384 S.E.2d 785, 797 (Va. 1989), *cert. denied*, 493 U.S. 1093 (1990).

262. *Pennington*, 393 S.E.2d at 852-53. Indices of reliability include (1) the expert's use of established techniques, (2) the expert's professional background, (3) the use of visual aids to assist the jury, and (4) the independent research conducted by the expert. *Id.* See also *State v. Ford*, 392 S.E.2d 781, 783 (S.C. 1990) (following a similar test).

263. *Spencer*, 384 S.E.2d at 783. Although the court rejected the *Frye* test, it did find that DNA evidence would meet that test. *Id.* at 783 n.10.

264. 113 S. Ct. 2786 (1993).

265. *Id.* at 2790, 2793.

266. *Id.* at 2794.

or evidence admitted is not only relevant, but reliable."²⁶⁷ Determining reliability entails a preliminary assessment of "whether the reasoning or methodology underlying the [expert] testimony is scientifically valid and . . . whether [the] reasoning or methodology properly can be applied to the facts in issue."²⁶⁸ In addition to Rule 702, the trial court must also consider other applicable rules, including Rule 703²⁶⁹ and Rule 403,²⁷⁰ in determining the admissibility of the scientific evidence in question.²⁷¹

1. Application in Federal Courts

Since *Daubert*, several cases involving the admissibility of DNA evidence have been decided by the federal courts. The Sixth Circuit Court of Appeals applied the *Daubert* analysis in *United States v. Bonds*.²⁷² DNA evidence found admissible in the lower court under the *Frye* test was also found admissible under *Daubert*.²⁷³ Similarly, the Eighth Circuit Court of Appeals applied *Daubert* in its review of a case decided under the *Castro* test.²⁷⁴ The Eighth Circuit concluded that the *Daubert* requirements for admissibility had been met under the more stringent *Castro* test.²⁷⁵ The District Court of the Virgin Islands also applied *Daubert* in determining that DNA evidence was admissible.²⁷⁶

267. *Id.* at 2795. The relevance requirement arises from the Rule 702 requirement that the testimony "assist the trier of fact to understand the evidence or to determine a fact in issue." *Id.* The reliability requirement is based on the Rule 702 requirement that the subject of an expert's testimony be scientific knowledge. *Id.*

268. *Id.* at 2796. The Court provided a non-exclusive list of factors that could be used to determine scientific validity:

- (1) whether a theory or technique can be (and has been) tested, (2) whether the theory or technique has been subjected to peer review and publication, (3) the known or potential rate of error in using a particular scientific technique and the existence and maintenance of standards controlling the technique's operation, and (4) whether the theory or technique has been generally accepted in the particular scientific field.

Id. at 2796-97.

269. Rule 703 provides that the expert may give an opinion based on facts or data not normally admissible if such facts or data are of a type reasonably relied upon by experts in that field. FED. R. EVID. 703.

270. See *supra* note 207 for the text of Rule 403 (stating the standard for weighing the probativeness of the evidence against possible prejudicial value).

271. *Daubert*, 113 S. Ct. at 2797-98.

272. 12 F.3d 540, 556-63 (6th Cir. 1993). Appellants include Steven Yee, defendant in *United States v. Yee*, 134 F.R.D. 161 (N.D. Ohio 1991). The court applied the *Frye* test in *Yee*. 134 F.R.D. at 164-65.

273. 12 F.3d at 566.

274. *United States v. Martinez*, 3 F.3d 1191, 1196 (8th Cir. 1993). The *Frye*-plus test previously used by the Eighth Circuit in *United States v. Two Bulls* is no longer binding authority. *Id.* at 1194 n.3.

275. 3 F.3d at 1198-99.

276. *Government v. Penn*, 838 F. Supp 1054, 1065-66, 1073-74 (D. V.I. 1993).

2. Application in State Courts

Thus far, no state court has rejected the *Frye* standard to follow *Daubert*. The Arizona Supreme Court decided that a case addressing the admissibility of DNA evidence was "not the case to determine whether Arizona should follow *Daubert*."²⁷⁷ The court found that the complexities and evolving nature of DNA technology made DNA testing "probably the worst subject to use" to decide whether to replace *Frye* with the *Daubert* test.²⁷⁸

An Illinois appellate court held that *Daubert* was inapplicable in determining whether the trial court properly admitted DNA evidence because the Illinois Supreme Court had expressly adopted the *Frye* standard.²⁷⁹ The appellate court left the decision of whether Illinois courts will continue to recognize the *Frye* standard to the Illinois Supreme Court.²⁸⁰

The Delaware Supreme Court found that the relevancy-plus approach²⁸¹ used by the trial court in determining the admissibility of DNA evidence was consistent with *Daubert*.²⁸² Similarly, the Wyoming Supreme Court rejected the *Frye* test in favor of the Wyoming Rules of Evidence, mirroring the decision in *Daubert*.²⁸³

IV. CURRENT STATUS OF DNA EVIDENCE ADMISSIBILITY

A. Admissibility in the Federal Courts

Federal appellate courts in the Second, Sixth, and Eighth Circuits have ruled on the admissibility of forensic DNA testimony and evidence.²⁸⁴ In *United States v. Jakobetz*,²⁸⁵ the Second Circuit Court of Appeals affirmed the district court admission of DNA profiling evidence.²⁸⁶ Rejecting the defense's challenge to the reliability of the sta-

277. *State v. Bible*, 858 P.2d 1152, 1183 (Ariz. 1993).

278. *Id.* at 1183. The court applied the *Frye* test, leaving *Daubert* "for another day." *Id.* See also *Commonwealth v. Crews*, 640 A.2d 395, 400 n.2 (Pa. 1994).

279. *People v. Mehlberg*, 618 N.E.2d 1168, 1191 n.1 (Ill. App. Ct., *appeal denied*, 624 N.E.2d 813 (Ill. 1993)).

280. *Id.* See also *People v. Watson*, 629 N.E.2d 634, 641 (Ill. App. Ct. 1994).

281. See *supra* notes 253-57 and accompanying text for a discussion of the relevancy-plus approach.

282. *Nelson v. State*, 628 A.2d 69, 73-74 (Del. 1993). According to the court, before scientific evidence could be admitted under *Daubert*, the evidence had to be found relevant and reliable. This test was met by the five-step test used by the trial court. The five-step test was based on the Delaware Rules of Evidence. *Id.*

283. *Springfield v. State*, 860 P.2d 435, 443 (Wyo. 1993).

284. See *United States v. Bonds*, 12 F.3d 540, 556 (6th Cir. 1993); *United States v. Martinez*, 3 F.3d 1191, 1198-99 (8th Cir. 1993); *United States v. Jakobetz*, 955 F.2d 786, 799 (2d Cir.), *cert. denied*, 113 S. Ct. 104 (1992).

285. 955 F.2d 786 (2d Cir. 1992), *cert. denied*, 113 S. Ct. 104 (1992).

286. *Id.* at 799-800. The district court found both the RFLP and statistical analyses to be sufficiently reliable to be presented to the jury. *Id.* at 789, 798-99. Based on the

tistical analysis, the district court found that the conservative methods and calculations used by the testing laboratory more than compensated for any potential errors from technological or sampling limitations or from any substructure in the database populations.²⁸⁷

In *United States v. Bonds*,²⁸⁸ the Sixth Circuit Court of Appeals upheld the district court's decision to admit expert testimony concerning DNA evidence.²⁸⁹ The case was originally decided under the *Frye* test and affirmed under *Daubert*.²⁹⁰ The court of appeals stated that its conclusion was not "altered by the numerous substantive, heated disputes over the procedures that the FBI used and over the accuracy of the results that these procedures produced."²⁹¹ Specifically, that questions about the possibilities of population substructure go to the weight of the evidence, not to admissibility.²⁹²

In *United States v. Martinez*,²⁹³ the Eighth Circuit Court of Appeals also affirmed the admissibility of DNA profiling evidence.²⁹⁴ Under the *Frye-Castro* test,²⁹⁵ the district court had held that the DNA testing procedures were admissible.²⁹⁶ The probability statistics, however, were found more prejudicial than probative and were excluded by the lower court.²⁹⁷ On appeal, the court of appeals affirmed the admissibility of the testing procedures under both the *Frye-Castro* test and the *Daubert* test.²⁹⁸

district court findings and on appellate review, the court of appeals stated that a court "could properly take judicial notice of the general acceptability of the general theory and the use of these specific techniques." *Id.* at 799.

287. *Id.* at 798-99.

288. 12 F.3d 540 (6th Cir. 1993).

289. *Id.* at 549-50.

290. *Id.* at 551 n.7.

291. *Id.* at 568.

292. *Id.* at 563.

293. 3 F.3d 1191, 1198-99 (8th Cir. 1993).

294. *Id.* The court of appeals stated that future courts can take judicial notice of the reliability of the general theory and techniques of DNA profiling. *Id.* at 1197. The Eighth Circuit also had addressed DNA admissibility in *United States v. Two Bulls*, a case that was subsequently rendered moot. See 918 F.2d 56 (8th Cir. 1990), *vacated, reh'g granted, dismissed as moot*, 925 F.2d 1127 (8th Cir. 1991); *Martinez*, 3 F.3d at 1194 n.3.

295. See *supra* notes 231-36 and accompanying text for a discussion of the *Frye-Castro* test.

296. *Martinez*, 3 F.3d at 1193.

297. *Id.*

298. *Id.* at 1198-99. The defendant argued on appeal that the exclusion of the probability evidence prejudiced him because the jury would conclude that he was the only source of the DNA found on the victim. The court held that the defendant was barred from raising the argument because of his earlier request that the statistical evidence be excluded from the trial. *Id.* at 1199. See *supra* notes 264-83 and accompanying text for a discussion of the *Daubert* test.

B. Admissibility in State Courts

At the present time, there is no consensus among state courts on the issue of DNA admissibility. Of the thirty-seven states and the District of Columbia that have decided the issue,²⁹⁹ twenty-seven states admit both DNA testing results and probability statistics, three states admit only the testing results, and four states do not admit DNA evidence. In three states and the District of Columbia, the admissibility issue is awaiting a determination on remand.

1. Test Results and Probability Statistics Admissible

a. Evidence Found to Be Acceptable/Relevant

Twenty-seven jurisdictions now hold that both DNA test results and probability statistics are admissible in criminal trials.³⁰⁰ These courts

299. Appellate courts in the following 13 states have not decided the issue of DNA admissibility: Alaska, Connecticut, Idaho, Maine, Montana, Nebraska, Nevada, North Dakota, Oklahoma, Rhode Island, Utah, Vermont, and Wisconsin.

In Wisconsin, DNA evidence has appeared in cases on appeal before the court of appeals, but the decisions do not indicate whether the court considered the issue of admissibility. See *e.g.*, *State v. Messelt*, 504 N.W.2d 362, 365 (Wis. Ct. App. 1993) (mentioning the impact of publicity about DNA evidence before trial on defendant's motion for change of venue); *State v. Wirth*, No. 91-2378-CR, 1992 WL 414516, at *3-4 (Wis. Ct. App. Nov. 10, 1992) (relating only to blood type statistics used in a probable cause issue), *rev. denied*, 497 N.W.2d 131 (Wis. 1993).

In Connecticut and Oklahoma, the appellate courts have not decided the issue of DNA evidence admissibility. DNA evidence, however, is being admitted at the trial court level. See *State v. Hammond*, 604 A.2d 793, 801 (Conn. 1992) (indicating DNA evidence is admissible at the trial court level, but refusing to take judicial notice of DNA typing because it is too novel); *Sadler v. State*, 846 P.2d 377, 381-82 (Okla. Ct. Crim. App. 1993) (discussing the state's failure to disclose DNA test results to defendant until trial).

In *State v. Houser*, 490 N.W.2d 168 (Neb. 1992), the Nebraska Supreme Court disallowed DNA evidence on the ground that the trial court had not determined the admissibility of the evidence. *Id.* at 181. The court remanded the case with a set of six factors the trial court must analyze before deciding whether the DNA evidence was admissible. *Id.* at 184.

In Vermont, the trial court excluded the DNA evidence on the basis that the probability analysis was flawed. *State v. Passino*, 640 A.2d 547, 549 (Vt. 1994). According to the court, because the probability estimates were such an integral part of the DNA profile, the test results were not admissible without reliable statistics. *Id.* The issue was not appealed.

300. The states that currently admit both DNA testing results and probability calculations are: Alabama, *Perry v. State*, 606 So. 2d 224, 226 (Ala. Crim. App. 1992); *but see Ex parte Perry*, 586 So. 2d 242, 251 (Ala. 1991) (finding testimony insufficient to establish validity or acceptance of tests performed); Arkansas, *Swanson v. State*, 823 S.W.2d 812, 814-16 (Ark. 1992); Colorado, *Fishback v. People*, 851 P.2d 884, 893-94 (Colo. 1993); Georgia, *Hornsby v. State*, 436 S.E.2d 767, 769 (Ga. Ct. App. 1993); *but see Caldwell v. State*, 393 S.E.2d 436, 444 (Ga. 1990) (finding population statistics not admissible because state did not establish that database populations were in Hardy-Weinberg equilibrium); Hawaii, *State v. Montalbo*, 828 P.2d 1274, 1280-83 (Haw. 1992); Indiana,

have found DNA evidence acceptable under the *Frye* test or relevant and not prejudicial under the relevancy test.³⁰¹ While the large majority of decisions involved the RFLP test, five courts have found the results of the PCR test admissible.³⁰²

b. Questions About Probability Statistics

Two of the courts admitting both test results and probability statistics have considered whether the statistical evidence will continue to be admissible in the future. In *Prater v. State*,³⁰³ expert witnesses for the state successfully rebutted the defense's criticism that the database used in determining band frequencies was not representative of the population at large.³⁰⁴ However, according to the Arkansas Supreme Court, the fact that there was "no meaningful attack on the population

Hopkins v. State, 579 N.E.2d 1297, 1304 (Ind. 1991); Iowa, State v. Brown, 470 N.W.2d 30, 32-33 (Iowa 1991); Kansas, Smith v. Deppish, 807 P.2d 144, 159 (Kan. 1991); Kentucky, Harris v. Commonwealth, 846 S.W.2d 678, 681 (Ky. 1992); Louisiana, State v. Quatrevingt, 617 So. 2d 484, 490, 492 (La. Ct. App. 1992); Maryland, Cobey v. State, 559 A.2d 391, 398 (Md. Ct. Spec. App.), *cert. denied*, 565 A.2d 670 (Md. 1989); Michigan, People v. Adams, 489 N.W.2d 192, 197-98 (Mich. Ct. App. 1992), *judgment modified and remanded in part, cert. denied in part*, 497 N.W.2d 182 (Mich. 1993); Minnesota, State v. Bloom, No. C9-94-55, 1994 WL 169980 (Minn. Apr. 29, 1994); Missouri, State v. Davis, 814 S.W.2d 593, 600-03 (Mo. 1991), *cert. denied*, 112 S. Ct. 911 (1992); New Jersey, State v. Williams, 599 A.2d 960, 968 (N.J. Super. Ct. 1991); New York, People v. Wesley, 633 N.E.2d 451, 455 (N.Y. 1994); *but see* People v. Keene, 591 N.Y.S.2d 733, 740 (Sup. Ct. 1992) (finding technique used to correct for band shifting not generally accepted and therefore proof of DNA typing not admissible); People v. Castro, 545 N.Y.S.2d 985, 995, 999 (Sup. Ct. 1989) (finding laboratory failed to perform accepted scientific techniques, therefore, evidence not admissible); North Carolina, State v. Pennington, 393 S.E.2d 847, 854 (N.C. 1990); Ohio, State v. Pierce, 597 N.E.2d 107, 115 (Ohio 1992); Oregon, State v. Futch, 860 P.2d 264, 270, 273 (Or. Ct. App. 1993); South Carolina, State v. Ford, 392 S.E.2d 781, 784 (S.C. 1990); South Dakota, State v. Wimberly, 467 N.W.2d 499, 506 (S.D. 1991); Tennessee, State v. Harris, 866 S.W.2d 583, 587 (Tenn. Crim. App. 1992); Texas, Kelly v. State, 824 S.W.2d 568, 574 (Tex. Crim. App. 1992); Virginia, Spencer v. Commonwealth, 384 S.E.2d 785, 797 (Va. 1989), *cert. denied*, 493 U.S. 1093 (1990); Washington, State v. Kalakosky, 852 P.2d 1064, 1073 (Wash. 1993); West Virginia, State v. Woodall, 385 S.E.2d 253, 260 (W.Va. 1989) (recognizing that DNA testing is generally accepted as to reliability but finding results of test were inconclusive and therefore inadmissible); Wyoming, Springfield v. State, 860 P.2d 435, 442-48 (Wyo. 1993); *but see* Rivera v. State, 840 P.2d 933, 941-42 (Wyo. 1992) (finding DNA evidence admissible, but better practice would have been not to refer to statistical probability when introducing DNA test results).

301. See, e.g., People v. Castro, 545 N.Y.S.2d 985, 995 (Sup. Ct. 1989) (finding that DNA forensic identification tests are reliable and meet the *Frye* standard of admissibility); Futch, 860 P.2d at 270 (concluding that forensic DNA testing has sufficient scientific reliability so as to have probative value).

302. See *supra* note 61 for a list of the five courts that admit evidence obtained by the PCR technique.

303. 820 S.W.2d 429 (Ark. 1991).

304. *Id.* at 438-39 (explaining that conservative probabilities may correct any deviation problems in population genetics).

genetics in this case" did not mean that there could not be a successful attack in future cases.³⁰⁵

In *Fishback v. People*,³⁰⁶ the Colorado Supreme Court held that the process used to produce DNA typing evidence and statistical frequencies was generally accepted in the relevant scientific community at the time the evidence was offered at trial.³⁰⁷ The court noted, however, that considerable debate had emerged concerning the acceptability of the statistical frequencies since that time.³⁰⁸ The supreme court reserved determination of the acceptability issue to future cases.³⁰⁹

One court limited the statistical evidence to a reduced probability calculation. In *Caldwell v. State*,³¹⁰ evidence that the laboratory database population was not in Hardy-Weinberg equilibrium³¹¹ was not disputed.³¹² The Georgia Supreme Court found, however, that conservative calculations may correct Hardy-Weinberg deviation problems.³¹³ Thus, such conservative calculations were held admissible.³¹⁴

Not all courts have found that questions concerning the reliability of the probability calculations necessitate exclusion of DNA evidence. In *State v. Futrell*,³¹⁵ the North Carolina Court of Appeals found that conflicting expert testimony about statistical procedures did not suggest "prejudice so unfair" nor show those procedures to be so "totally unreliable" as to require exclusion.³¹⁶ The court held that conflicting expert testimony goes to expert credibility, and the jury is to determine the weight each expert's testimony should receive.³¹⁷ Similarly, the Wyoming Supreme Court found that questions concerning the size of the reference database or questions about Hardy-Weinberg equilibrium went to the weight of the evidence and were for the jury to consider.³¹⁸

305. *Id.* at 439.

306. 851 P.2d 884 (Colo. 1993).

307. *Id.* at 894.

308. *Id.*

309. *Id.* at 895.

310. 393 S.E.2d 436 (Ga. 1990).

311. See *supra* notes 191-94 and accompanying text for an explanation of Hardy-Weinberg equilibrium.

312. 393 S.E.2d at 443-44.

313. *Id.* at 444.

314. *Id.* The original frequency calculation was one in 24 million; the more conservative figure was one in approximately 250,000. *Id.* at 443-44. The court remanded the case so that the more conservative figures could be used. *Id.* at 444.

315. 436 S.E.2d 884 (N.C. Ct. App. 1993).

316. *Id.* at 890-91 (quoting *State v. Bruno*, 424 S.E.2d 440, 445-46 (N.C. Ct. App. 1993)).

317. *Id.* at 891.

318. *Springfield v. State*, 860 P.2d 435, 447 (Wyo. 1993).

2. Test Results Admissible; Probability Statistics Not Admissible

While the majority of state courts admit both test results and probability statistics, questions concerning the reliability of the probability statistics have led courts in three states to limit admissibility to test results only. In *State v. Bible*,³¹⁹ the Arizona Supreme Court refused to admit the probability statistics because the laboratory's calculations did not meet the *Frye* test.³²⁰ Specifically, the court criticized the laboratory's use of the product rule³²¹ when the database was not in Hardy-Weinberg equilibrium.³²²

In *Polk v. State*,³²³ the Mississippi Supreme Court found that the testing results satisfied the *Frye* test.³²⁴ The trial court, however, had ruled the population statistics inadmissible, and the issue was not addressed on appeal.³²⁵

In *Commonwealth v. Crews*,³²⁶ the Pennsylvania Supreme Court held that while identifying a match by comparing DNA test results met the *Frye* test, the statistical analysis did not.³²⁷ Testimony as to the match results was therefore admissible, but the statistical analysis was not.³²⁸ Pennsylvania had previously admitted both test results and statistical evidence.³²⁹

319. 858 P.2d 1152 (Ariz. 1993).

320. *Id.* at 1189.

321. See *supra* notes 195-98 and accompanying text for a definition of the product rule.

322. *Bible*, 858 P.2d at 1188-89. According to the court, the probability calculations were also flawed because they were based on the disputed assumption of linkage equilibrium and the database relied on was of disputed statistical validity. *Id.* See *supra* notes 191-98 and accompanying text for an explanation of Hardy-Weinberg and linkage equilibrium.

323. 612 So. 2d 381 (Miss. 1992).

324. *Id.* at 393. The court used the *Frye-Castro* test as adapted by the Alabama court in *Ex parte Perry*. *Id.* at 390. Cf. *Ex parte Perry*, 586 So. 2d 242, 250 (Ala. 1991). The first two prongs of the *Perry* test are identical to the *Frye-Castro* test. The third prong, however, requires that the testing laboratory perform the generally accepted techniques *without error* in the performance or interpretation. *Polk*, 612 So. 2d at 390 (emphasis added). See *supra* notes 230-36 for a discussion of the *Frye-Castro* test.

325. *Polk*, 612 So. 2d at 390, 392. The trial court offered no explanation for finding the evidence inadmissible.

326. 640 A.2d 395 (Pa. 1994).

327. *Id.* at 402.

328. *Id.* The expert was allowed to testify that the samples taken from the crime scene were "extremely strongly associated" with the defendant. *Id.*

329. See *Commonwealth v. Rodgers*, 605 A.2d 1228, 1235 (Pa. Super. Ct. 1992).

3. Test Results and Probability Statistics Not Admissible

Four states³³⁰ do not admit either DNA test results or probability statistics. These courts base their decisions primarily on problems associated with the probability statistics.

a. No General Acceptance

Courts in three states exclude DNA evidence on the basis that the statistical calculation process lacks general acceptance in the relevant scientific community.³³¹

California, which earlier admitted both test results and probability statistics,³³² now admits neither. In *People v. Barney*,³³³ the court found that there was "a fundamental disagreement among population geneticists concerning the determination of the statistical significance of a match of DNA patterns."³³⁴ To the court, this disagreement "demonstrates indisputably that there is no general acceptance of the current [statistical calculation] process."³³⁵ The court went on to say that "[t]he error infects the underlying match evidence, which is incomplete without an interpretation of its significance."³³⁶ Evidence of both the match and the statistical probabilities were, therefore, inadmissible.³³⁷ The same reasoning was followed in a later California case.³³⁸

Massachusetts³³⁹ and New Mexico³⁴⁰ also exclude DNA evidence on the basis of the lack of general acceptance of the statistical calculation process. As in California, evidence of a match was found to be mean-

330. California, *People v. Barney*, 10 Cal. Rptr. 2d 731, 745 (Ct. App. 1992); Delaware, *Nelson v. State*, 628 A.2d 69, 76 (Del. 1993); Massachusetts, *Commonwealth v. Lanigan*, 596 N.E.2d 311, 316 (Mass. 1992); New Mexico, *State v. Anderson*, 853 P.2d 135, 146-47 (N.M. Ct. App.), cert. granted, 848 P.2d 531 (N.M. 1993).

331. California, *Barney*, 10 Cal. Rptr. 2d at 745; Massachusetts, *Lanigan*, 596 N.E.2d at 314-17; New Mexico, *Anderson*, 853 P.2d at 146-47.

332. See *People v. Axell*, 1 Cal. Rptr. 2d 411, 430-31 (Ct. App. 1991).

333. 10 Cal. Rptr. 2d 731 (Ct. App. 1992).

334. *Id.* at 740. The court based this finding on articles appearing in the December 20, 1991 issue of *Science*. *Id.* See Lewontin & Hartl, *supra* note 200 at 1745; Chakraborty & Kidd, *supra* note 200, at 1735. The court concluded that these articles "vividly demonstrate not merely a current absence of general acceptance, but the presence of a 'bitter' and 'raging' disagreement among population geneticists." *Barney*, 10 Cal. Rptr. 2d at 743 (citing Leslie Roberts, *Fight Erupts Over DNA Fingerprinting*, 254 Sci. 1721, 1721 (1991)).

335. 10 Cal. Rptr. 2d at 744.

336. *Id.* at 745.

337. *Id.* The court, however, held that admitting the evidence was harmless error in this case. *Id.* at 747.

338. *People v. Wallace*, 17 Cal. Rptr. 2d 72 (Ct. App. 1993). As in *Barney*, the admission of the DNA evidence was harmless error. *Id.* at 727.

339. *Commonwealth v. Lanigan*, 596 N.E.2d 311, 316 (Mass. 1992).

340. *State v. Anderson*, 853 P.2d 135, 146-47 (N.M. Ct. App.), cert. granted, 848 P.2d 531 (N.M. 1993).

ingless without the statistical probability; therefore, evidence of both the match and the frequency estimates was excluded.³⁴¹

b. Only One Side Presented

In *State v. Nelson*,³⁴² a Delaware trial court admitted evidence of a match but refused to admit the accompanying statistical evidence.³⁴³ The court found that the statistical analysis had not been subjected to any serious scientific challenge in the case.³⁴⁴ The court would not allow the testimony about statistical probability evidence because of a concern about its prejudicial effect on the jury.³⁴⁵

On appeal, the Delaware Supreme Court disallowed evidence of the match in the absence of the statistical interpretation of the significance of the match.³⁴⁶ The court left the question of the admissibility of statistical calculation evidence to another day.³⁴⁷

All four of these courts have suggested that DNA evidence may be admissible in the future.³⁴⁸ At the present time, the evidence is inadmissible because there is substantial disagreement within the field of population genetics about the reliability of the population statistics. Once these courts find agreement within the scientific community that probability calculations are reliable, the probability calculations and the test match will be admissible.³⁴⁹

341. *Lanigan*, 596 N.E.2d at 314-17; *Anderson*, 853 P.2d at 146-47.

342. Nos. IK89-09-0882 to 0884, 1991 WL 190308 (Del. Super. Ct. Oct. 17, 1991), *appeal denied*, 608 A.2d 730 (Del. 1991).

343. *Id.* at *8.

344. *Id.*

345. *Id.*

346. *Nelson v. State*, 628 A.2d 69, 76 (Del. 1993). The Delaware Supreme Court held that the reliability of the statistical calculations should be left for a trial where scientific evidence was presented on both sides of the issue. *Id.* at 76-77. Nevertheless, the supreme court held that the admission was harmless error. *Id.* at 77.

347. *Id.* at 76. The court declined to address this issue because of the inadequate record. *Id.*

348. *People v. Barney*, 10 Cal. Rptr. 2d 731, 745 (Ct. App. 1992) (stating that if the conservative calculation methods become generally accepted by population geneticists, then DNA evidence will become admissible in California); *State v. Nelson*, 628 A.2d 69, 77 (Del. 1993) (suggesting that subsequent cases should look at the "peer literature" in this "rapidly advancing scientific field"); *Commonwealth v. Lanigan*, 596 N.E.2d 311, 316 (Mass. 1992) (indicating that once science supports the conservative calculations, the result may be different than in the present case); *State v. Anderson*, 853 P.2d 135, 147 (N.M. Ct. App.) (basing decision only on current scientific thought), *cert. granted*, 848 P.2d 531 (N.M. 1993).

349. *See, e.g., Nelson*, 628 A.2d at 76 (indicating that DNA evidence will be admissible when the scientific literature supports admission of the statistics).

4. Awaiting Admissibility Determinations

Trial courts in Illinois, New Hampshire, and the District of Columbia excluded DNA evidence on the ground that the statistical technique used to estimate population frequencies was not generally accepted in the relevant scientific community. All three cases were appealed and subsequently remanded to determine whether there was consensus within the scientific community for a more conservative method of calculating population frequencies.

In *People v. Watson*,³⁵⁰ the Illinois Court of Appeals found that the methodology used to generate the probability statistics was not generally accepted by the relevant scientific community. The court also concluded that while the testing procedures were capable of giving reliable results, such results were not admissible without probability statistics.³⁵¹

The court remanded the case for a determination as to whether the "ceiling principle"³⁵² was admissible under *Frye* for calculating the probability estimate.³⁵³ If the trial court concluded that the ceiling principle was generally accepted, evidence of the match and an appropriate probability estimate would be admissible. If the ceiling principle did not meet the *Frye* test, all DNA evidence was to be excluded.³⁵⁴

350. 629 N.E.2d 634 (Ill. App. Ct. 1994).

351. *Id.* at 644. The court declined to follow earlier Illinois Court of Appeals decisions affirming the admissibility of DNA evidence. *Id.* at 643. The court was reluctant to place undue reliance on the earlier cases because in each there was "a complete absence of opposing scientific perspectives challenging the DNA evidence." *Id.*

The Illinois appellate courts are not in agreement on the issue of DNA admissibility. The first district appellate court has found that the methodology used to calculate the probability statistics is not generally accepted. *Watson*, 629 N.E.2d at 644. The *Watson* court remanded the case for a determination as to whether a more conservative methodology would be acceptable under *Frye*. *Id.* at 647.

However, the second district appellate court has found the procedures used to develop and interpret the test results and to calculate the probability estimates to be generally accepted by the relevant scientific community. *People v. Stremmel*, 630 N.E.2d 1301, 1310 (Ill. App. Ct. 1994). The *Stremmel* court affirmed the trial court decision to admit both the test results and the probability estimates. *Id.*

The fourth district appellate court has also found DNA evidence admissible. See *People v. Johnson*, No. 4-93-0558, 1994 WL 245739, at *3, *4 (Ill. App. Ct. June 7, 1994); *People v. Miles*, 577 N.E.2d 477, 484-85 (Ill. App. Ct. 1991); *People v. Lipscomb*, 574 N.E.2d 1345, 1357 (Ill. App. Ct. 1991). In *Johnson*, the court declined to follow *Watson*, but rather affirmed the holdings in *Miles* and *Lipscomb*. *Johnson*, 1994 WL 245739, at *4. In *Johnson*, however, the defendant did not question the reliability of the DNA procedures. *Id.* at *3, *4.

The fifth district appellate court has also found DNA evidence to be admissible. See *People v. Mehlberg*, 618 N.E.2d 1168, 1196 (Ill. App. Ct. 1993).

352. See *supra* note 194 for an explanation of the "ceiling principle."

353. *Watson*, 629 N.E.2d at 647.

354. *Id.* at 648.

In *State v. Vandebogart*,³⁵⁵ the New Hampshire Supreme Court found the theory underlying DNA profiling and the technology used to declare a match to be generally accepted in the relevant scientific community.³⁵⁶ The method used for calculating population frequencies, however, had not found general acceptance and, therefore, was not admissible.³⁵⁷

Since evidence of a match was "virtually meaningless without a statistical probability expressing the frequency with which a match could occur,"³⁵⁸ evidence of a match would not be admissible unless accompanied by an admissible population frequency estimate.³⁵⁹ The court remanded the case for a determination of whether the more conservative "ceiling principle" had achieved general acceptance in the relevant scientific community.³⁶⁰

In *United States v. Porter*,³⁶¹ the District of Columbia Court of Appeals found that the procedure for calculating coincidental match probabilities was not based on generally accepted techniques and, therefore, was inadmissible.³⁶² The court remanded the case for a determination as to whether the requisite consensus now existed for a more conservative probability calculation.³⁶³

In Florida, DNA evidence had been found admissible under the relevancy test.³⁶⁴ The Florida Supreme Court, however, later held that the correct standard for admitting scientific evidence was the *Frye* test.³⁶⁵ In a recent district court of appeals decision, the court held that the method used to determine the population frequency did not meet the *Frye* standard and was therefore not admissible.³⁶⁶ The court, however, deferred to testimony that a more conservative population frequency

355. 616 A.2d 483 (N.H. 1992).

356. *Id.* at 494.

357. *Id.* The relevant scientific community in this instance was the field of population genetics. *Id.*

358. *Id.*

359. *Id.*

360. *Vandebogart*, 616 A.2d at 495. The court stated that if the ceiling principle was found to be a generally accepted technique, the trial court was then to decide whether admission of the population statistic was harmless error. *Id.*

361. 618 A.2d 629 (D.C. 1992).

362. *Id.* at 630-31.

363. *Id.* at 642. The *Porter* court quotes at length from *United States v. Bridgett*, 120 DAILY WASH. L. RPT. 1697, 1700-01 (Super. Ct. D.C. 1992). The *Bridgett* court held that a more conservative estimate based on the modified ceiling principle was admissible. *Porter*, 618 A.2d at 643. The *Porter* court stated that on remand the trial court should address the applicability of the *Bridgett* holding. *Id.* at 644.

364. See *Robinson v. State*, 610 So. 2d 1288 (Fla. 1992), *cert. denied*, 114 S. Ct. 1205 (1994); *Martinez v. State*, 549 So. 2d 694 (Fla. Dist. Ct. App. 1989); *Andrews v. State*, 533 So. 2d 841 (Fla. Dist. Ct. App. 1988), *rev. denied*, 542 So. 2d 1332 (Fla. 1989).

365. *Flanagan v. State*, 625 So. 2d 827, 828 (Fla. 1993).

366. See *Vargas v. State*, Nos. 92-556, 92-557, 1994 WL 231360, at *13 (Fla. Dist. Ct. App. June 1, 1994).

could be calculated.³⁶⁷ The matter was remanded for a determination as to whether a more conservative method of calculating population frequencies had achieved general acceptance.³⁶⁸

C. *The Minnesota Approach*

1. *First Impression*

The admissibility of forensic DNA evidence was an issue of first impression for the Minnesota Supreme Court in *State v. Schwartz*.³⁶⁹ The court first reaffirmed the *Frye* test as the appropriate standard to determine the admissibility of novel scientific evidence.³⁷⁰ The court then concluded that forensic DNA typing had gained general acceptance in the scientific community.³⁷¹

General acceptance under the *Frye* test, however, was not enough.³⁷² According to the court, admissibility of the test results in a particular case would depend on the laboratory's compliance with appropriate standards and controls and the availability of the testing data and results.³⁷³ In the case at hand, the laboratory had not complied with certain validation protocols.³⁷⁴ The court, therefore, found that the test results lacked foundational adequacy and were inadmissible.³⁷⁵

The court added that while test results would be admissible if the standard was met, "a limitation on the use of population frequency statistics is necessary because of the danger that such evidence will have a 'potentially exaggerated impact on the trier of fact.'" ³⁷⁶ The court went on to hold that Minnesota trial courts should continue to rely on the limitation regarding statistical probability evidence set out in *State v. Joon Kyu Kim*.³⁷⁷

367. *Id.*

368. *Id.*

369. 447 N.W.2d 422, 425 (Minn. 1989).

370. *Id.* at 424. Although the court reaffirmed the *Frye* standard, it rephrased the standard to require that experts in the field generally agree that the evidence is reliable and trustworthy. *Id.*

371. *Id.* at 424-25.

372. In the words of the court, the "reliability of the test results is crucial." *Id.* at 426.

373. *Id.* at 428.

374. *State v. Schwartz*, 447 N.W.2d 442, 426-27 (Minn. 1989).

375. *Id.* at 428. The court found that the laboratory had not met all the minimum guidelines for formal methodology validation and published results of experimental studies in peer review journals. Also, the laboratory had not complied with all the standards established for DNA typing. *Id.* at 426-27.

376. *Id.* at 428 (quoting *State v. Joon Kyu Kim*, 398 N.W.2d 544, 548 (Minn. 1987)). In response to the state's request that the *Kim* limitation be rejected, the court confirmed its continuing conviction that juries in criminal cases "may give undue weight and deference to presented statistical evidence." *Id.* The court was reluctant to take that risk. *Id.*

377. *Schwartz*, 447 N.W.2d at 429. *Kim* was an appeal from a pretrial hearing in which the statistical frequency evidence derived from ABO blood type and red cell en-

2. Subsequent Application

In *State v. Nielsen*,³⁷⁸ the defendant contended that the trial court erred in admitting expert testimony relating to DNA typing and population frequency statistics.³⁷⁹ Avoiding the issue of whether the statistical evidence was improperly admitted, the court concluded that the error was harmless and the defendant was not entitled to relief.³⁸⁰

In both *State v. Jobe*³⁸¹ and *State v. Johnson*,³⁸² the DNA testing procedures were found to have met the *Schwartz* standards of admissibility.³⁸³ The DNA expert in *Johnson* was allowed to present the frequency statistic for each of the matched bands.³⁸⁴ The expert was not, however, allowed to draw any conclusions from the statistics or to testify to the frequency with which a match at all bands would occur.³⁸⁵

In *State v. Alt*,³⁸⁶ the Minnesota Court of Appeals found that the DNA test results and population frequency calculations for individual loci were admissible.³⁸⁷ The court, however, limited expert opinion to testimony that the test results were consistent with the defendant being the source of the DNA sample.³⁸⁸ Any testimony describing the significance of a match was barred under *Kim*.³⁸⁹

zyme testing was ruled inadmissible. *State v. Joon Kyu Kim*, 398 N.W.2d 544, 548 (Minn. 1987).

Under *Kim*, an expert could testify about the theory underlying the test, that the test did not exclude the suspect, and that the scientific evidence was consistent with the defendant as the source of the crime scene sample. *Id.* at 549. The expert, however, would not be permitted to express an opinion about the probability that the crime scene sample came from the defendant or an opinion as to how many individuals in the general population would have the same test results as the defendant. *Id.*

378. 467 N.W.2d 615 (Minn. 1991).

379. *Id.* at 619.

380. *Id.*

381. 486 N.W.2d 407 (Minn. 1992).

382. 498 N.W.2d 10 (Minn. 1993).

383. *Johnson*, 498 N.W.2d at 14; *Jobe*, 486 N.W.2d at 420.

384. *Johnson*, 498 N.W.2d at 14. The statistics showed that each of the bands appeared in three to eight percent of the Caucasian population database and in seven to 27 percent of the Native American population database. *Id.*

385. *Id.* The court compared the testimony admitted to how often one might expect to find white picket fences, blue awnings, two-car garages, and French doors on houses in a given neighborhood. The statistical frequency evidence that was excluded would have shown how often to expect to find a house with all those features in that neighborhood. *Id.* at 13.

386. 504 N.W.2d 38 (Minn. Ct. App. 1993).

387. *Id.* at 53-54. The statistical frequencies of individual loci were admissible if calculated according to the NRC modified ceiling principle. *Id.* at 51. See *supra* note 194 for a description of the modified ceiling principle of calculating population frequency statistics.

388. *Id.* at 53-54.

389. *Id.* at 53. Specifically, an expert could not testify that the defendant's DNA matched the crime scene sample to a "reasonable degree of scientific certainty." *Id.* at 52. See *supra* note 377 for a discussion of *Kim*.

3. Legislative Response

The exclusion of statistical population evidence by the Minnesota courts continued despite the Minnesota Legislature's explicit statutory approval of the use of these statistics in judicial proceedings.³⁹⁰ The Minnesota Supreme Court has not taken a position on this legislation other than to state that the supreme court, not the legislature, has "the primary responsibility for adopting rules relating to the admission of evidence in trials."³⁹¹

In response to the court's rejection of the legislature's power to promulgate evidentiary rules, the legislature amended Minnesota Statute section 480.0591 to specifically prevent the supreme court from making rules of evidence that conflict with statutes relating to the admissibility of statistical probability evidence based on genetic or blood test results.³⁹² The legislature also introduced a number of bills proposing a constitutional amendment mandating the admissibility of DNA statistical evidence. The court responded in *State v. Bloom*.³⁹³

4. State v. Bloom

In *State v. Bloom*, the Minnesota Supreme Court overruled its previous position on the inadmissibility of DNA statistical evidence.³⁹⁴ According to the court:

[T]he National Research Council's recent adoption of the conservative "interim ceiling method" for computation of the probability that a randomly selected person would have the same DNA profile as that of a sample of bodily fluids found at a crime scene justifies the creation of a DNA exception to the rule against the admission of statistical probability evidence in criminal prosecutions to prove identity.³⁹⁵

390. MINN. STAT. § 634.26 (1992). See *supra* note 5 for the text of section 634.26. Five other states have also enacted statutes that affect the admissibility of DNA evidence. See IND. CODE § 35-37-4-13(b) (1993); LA. REV. STAT. ANN. § 441.1 (West 1992); MD. CTS. & JUD. PROC. CODE ANN. § 10-915(b) (1993); TENN. CODE ANN. § 24-7-117 (1993); VA. CODE ANN. § 19.2-270.5 (Michie 1990).

391. *State v. Nielsen*, 467 N.W.2d 615, 620 (Minn. 1991) (citing a discussion of the separation of powers doctrine found in *State v. Willis*, 332 N.W.2d 180, 184 (Minn. 1983)). See also *State v. Alt*, 504 N.W.2d 38, 41 n.2 (Minn. Ct. App. 1993) (noting the legislature's questionable authority to enact evidentiary rules relating to DNA evidence).

392. MINN. STAT. § 480.0591 subd. 6 (1992) states:

The supreme court, however, shall not have the power to promulgate rules of evidence which conflict, modify, or supersede the following statutes: . . . (d) statutes which relate to the admissibility of statistical probability evidence based on genetic or blood test results, found in sections 634.25 to 634.30.

393. No. C9-94-55, 1994 WL 169980 (Minn. Apr. 29, 1994).

394. See also *State v. Perez*, 516 N.W.2d 175, 176 (Minn. 1994) (permitting testimony that defendant was the source of the DNA sample recovered from the crime scene); *State v. Bauer*, 516 N.W.2d 174, 175 (Minn. 1994) (allowing expert to testify that there was a "match").

395. *Bloom*, No. C9-94-55, 1994 WL 169980, at *1.

The court reached this decision notwithstanding the "intense debate" that continues regarding the most reliable and accurate way of estimating random match probability and the great difficulty in educating the jury as to precisely what such statistical figures mean and do not mean.³⁹⁶

For random match probability statistics to be admissible, the court held that the expert must be properly qualified, the evidentiary foundation must be sufficient, and the random match probability statistics must be based on the National Research Council's interim ceiling method.³⁹⁷

The court also held that a properly qualified expert may express the opinion that, "to a reasonable degree of scientific certainty," the defendant is (or is not) the source of the bodily evidence found at the crime scene.³⁹⁸ According to the court, this "modification of *Kim*" stems from the belief that the expert testimony limitations that were appropriate in *Kim* do not apply in the DNA context.³⁹⁹

The court will now allow the following expert opinion testimony: (1) that there is a match between the defendant's DNA profile and the DNA profile obtained from the crime scene; (2) that, given a reliable multi-locus match, the probability that the match is random or coincidental is extremely low; and (3) that to a reasonable scientific certainty, the defendant is (or is not) the source of the crime scene DNA.⁴⁰⁰

An expert is not allowed to say that a particular profile is unique or that the defendant is the source to the exclusion of all others.⁴⁰¹ Moreover, the expert is not permitted to express an opinion as to the strength of the evidence.⁴⁰²

With the admissibility of DNA evidence being debated in both the scientific and legal communities, and with other jurisdictions beginning to exclude DNA evidence, Minnesota now reverses its position and allows the statistical frequency data and the test results into evidence. Will the prophesy of Justice Coyne in her lone dissent to the *Bloom* opinion come true? Will the day come "when this court regrets [the *Bloom*] decision?"⁴⁰³

396. *Id.* at *9.

397. *Id.* A description of the ceiling method can be found *supra* at note 194.

398. *Id.* at *10.

399. Limiting expert testimony to opinions that the defendant's DNA was "consistent with" crime scene samples was appropriate when the underlying probability figures were one in 4500 or one in 1121. *Id.* at *9. Inferred from the opinion is that a "consistent with" limitation is no longer appropriate when the underlying probability figures reach one in 93,700 or one in 634,687, as they did in this case.

400. *Bloom*, No. C9-94-55, 1994 WL 169980, at *10.

401. *Id.*

402. *Id.*

403. *Id.*

V. CONCLUSION

Appellate courts in three federal jurisdictions, thirty-seven states, and the District of Columbia have ruled on the admissibility of forensic DNA evidence in the past six years. All three federal and twenty-seven state jurisdictions admit both DNA test results and the statistical probability calculations. Three states admit only testing results. Eight states and the District of Columbia do not admit DNA evidence or are awaiting admissibility decisions on remand.

With the court's decision in *Bloom*, Minnesota, which formerly admitted only the testing results, now also admits probability statistics. In his concurrence to the earlier *Schwartz* opinion, Justice Kelley remarked that "Minnesota stands alone in depriving the jury of this relevant and probative [statistical] evidence."⁴⁰⁴ This remark was made long before the debate regarding the reliability of statistical evidence began. With the court's decision in *Bloom*, Minnesota no longer stands alone.

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404. 447 N.W.2d at 429.

