Michael Devon Armstead v. State of Maryland, No. 133, 1993 Term.

EVIDENCE--Under Maryland Code (1974, 1995 Repl. Vol., 1995 Cum. Supp.) § 10-915 of the Courts and Judicial Proceedings Article, trial courts shall admit DNA evidence without a preliminary *Frye-Reed* or "inverse *Frye-Reed*" hearing on the theoretical basis of DNA testing or the restriction fragment length polymorphism (RFLP) process of DNA analysis.

EVIDENCE--Under Maryland Code (1974, 1995 Repl. Vol., 1995 Cum. Supp.) § 10-915 of the Courts and Judicial Proceedings Article, statistical probability evidence regarding the odds of a random DNA match shall be admitted whenever DNA evidence is offered to prove identity. Experts may use either the "product rule" or "ceiling principle" methodology of calculating the odds of a random match.

CONSTITUTIONAL LAW--The general theory of DNA testing, the process of restriction fragment length polymorphism (RFLP) DNA testing, and the methods of calculating population genetics statistics are sufficiently reliable to satisfy due process. Case-specific defects in the DNA testing process may render certain DNA evidence so unreliable that its admission in a particular case would violate due process. Therefore, the opponent of DNA evidence must have the opportunity to challenge case-specific defects in the DNA testing procedure.

EVIDENCE--Under Maryland Code (1974, 1995 Repl. Vol., 1995 Cum. Supp.) § 10-915 of the Courts and Judicial Proceedings Article, individualized errors in the application of the DNA analysis procedures ordinarily go to the weight of the evidence rather than its admissibility. Trial judges may exercise discretion to exclude DNA evidence, however, if such errors were made in the course of testing that the evidence would not be helpful to the factfinder. Trial judges may not exclude DNA evidence under the probative value/prejudicial effect balancing test in Maryland Rule 403.

IN THE COURT OF APPEALS OF MARYLAND

No. 133

September Term, 1993

MICHAEL DEVON ARMSTEAD

v.

STATE OF MARYLAND

Murphy, C.J.
Eldridge
Rodowsky
Chasanow
Karwacki
Bell
Raker

JJ.

Opinion by Raker, J.
Bell, J. dissents.

Filed: March 20, 1996

In this case we consider the statutory and constitutional limitations on the admissibility of deoxyribonucleic acid (DNA) evidence. Specifically, we must determine the effect of Maryland Code (1974, 1995 Repl. Vol., 1995 Cum. Supp.) § 10-915 of the Courts and Judicial Proceedings Article[1] on the admissibility of both the basic evidence of a DNA "match" and the descriptive statistics that are typically offered in support of a match. We shall hold that the statute renders both components of DNA evidence admissible. We shall also hold that the admission of DNA evidence in this case did not violate the Petitioner's due process rights.

I.

On January 29, 1991, the victim, a Howard County woman, was at home alone when an assailant broke into the home, demanded her money and valuables, and then raped her and forced her to perform fellatio. The State presented evidence that pointed to the Petitioner, Michael Devon Armstead, as the perpetrator of these offenses. First, following the attack, the victim provided the police with a description matching Armstead. The victim also selected Armstead's photograph from a photo array and identified him in court as the perpetrator. A neighbor who observed someone fleeing from the scene also identified Armstead as the perpetrator. In addition, when Armstead was arrested on the evening of the

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[1]Unless otherwise specified, all statutory cites herein are to Maryland Code (1974, 1995 Repl. Vol., 1995 Cum. Supp.) § 10-915 of the Courts and Judicial Proceedings Article.

incident, he was wearing a leather jacket matching the victim's description of the jacket worn by her attacker. The police also found a pair of pantyhose and a roll of duct tape in shrubbery near Armstead, which were both items that the perpetrator had used in the attack.

Physical evidence from the rape also linked Armstead to the crime. Semen was collected from the victim and analyzed using standard blood group testing. The blood group analysis indicated that Petitioner was within the 4.7% of the population that could have been the source of the semen. Finally, DNA analysis was performed using the restriction fragment length polymorphism (RFLP) testing method, revealing a "match" between the defendant's blood and the semen sample taken from the victim.

Armstead was indicted in the Circuit Court for Howard County on twenty-five counts,[2] including charges of first and second degree rape, first and second degree sexual offense, perverted practices, assault, battery, burglary, robbery, and theft.

Prior to trial, Armstead filed a motion *in limine* to exclude the DNA evidence on both statutory and constitutional grounds. His statutory argument was that § 10-915 permits what he described as an "inverse *Frye-Reed* hearing." He argued that, although the Legislature may have found RFLP testing reliable when it enacted

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[2]In the trial at issue in this appeal, Armstead was tried on twelve of the twenty-five charges. Ten of the remaining charges were severed, two were dismissed, and one was not prosecuted.

§ 10-915, this does not imply that the General Assembly intended the statute to preclude all future inquiry into the technique's reliability. In light of recent scientific developments, Petitioner argued, the State should have been required to prove *current* general acceptance as a prerequisite to admission of the DNA evidence.

Petitioner also asserted several constitutional arguments. First, he contended that § 10-915 was unconstitutionally vague and overbroad because it did not provide any standards for DNA testing. Second, he argued that the use of DNA evidence violated his right to due process under the Fourteenth Amendment of the United States Constitution and Article 24 of the Maryland Declaration of Rights because "an individual [must] not suffer punitive action as a result of an inaccurate scientific procedure." *Higgs v. Wilson*, 616 F. Supp. 226, 230 (W.D. Ky. 1985), *vacated and remanded on other grounds*, 793 F.2d 1291 (6th Cir. 1986), *aff'd in part, vacated in part, and remanded in part on other grounds sub nom Higgs v. Bland*, 888 F.2d 443 (6th Cir. 1991). Third, Armstead argued that the statute denied him his right to confrontation under both the federal and state constitutions. Finally, he argued that the statute violated separation of powers because the Legislature had invaded the province of the judiciary by enacting an evidentiary rule.

The trial court rejected Petitioner's statutory argument on

the grounds that the statute precluded the trial court from holding a hearing on the reliability of DNA evidence. The court held a five-day evidentiary hearing, however, to address his constitutional challenges.[3] At the hearing, much of Petitioner's argument focused on his due process claim. He specifically challenged the method used to calculate the odds of a random or coincidental match between his DNA and the DNA taken from the victim. Petitioner contended that the DNA evidence should be excluded because this probability calculation was based on a purportedly outmoded method known as the "product rule" rather than the newer "ceiling principle" method, rendering the data so unreliable as to deny him due process.

The trial court denied the motion *in limine*, ruling that the evidence was admissible by statute, that the statutory conditions for admissibility had been satisfied, and that Petitioner's constitutional arguments lacked merit. First, the court rejected Armstead's "void for vagueness" argument, holding that the vagueness doctrine did not apply to an evidentiary statute such as § 10-915. Second, the court rejected the Petitioner's due process argument because, after hearing extensive expert testimony, the court concluded that the testing procedures used by the laboratories in this case did not render the results so unreliable

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[3]For purposes of the DNA hearing, this case was consolidated with the unrelated case of defendant John Daniel Kelly.

as to violate Armstead's due process rights. Third, the court rejected Armstead's confrontation argument, finding that Armstead exercised his right to cross-examine the State's witnesses at the hearing, and that he would be afforded another opportunity to do so at trial. Finally, the court rejected the separation of powers argument, concluding that the Legislature possesses the authority to change the rules of evidence. The court therefore held that the DNA evidence would be admissible at trial.

Armstead was tried before a jury in the Circuit Court for Howard County. At trial, the State called several expert witnesses who presented both the product rule and ceiling principle calculations to the jury, explaining the rationale for each method. The witnesses explained that the product rule calculation yielded odds of a random match between Armstead's DNA and the DNA recovered from the victim of one in 480 million, while the ceiling principle calculation yielded odds of a random match of one in 800,000. The jury was also informed of the laboratory error rates. Petitioner did not call any expert witnesses at trial to challenge the State's DNA evidence; he did, however, cross-examine the State's experts and elicited testimony regarding the controversy over the proper method of calculating match probabilities.

On December 9, 1992, the jury convicted Armstead of first degree rape, first degree sexual offense, perverted practices, assault, burglary, and attempted robbery. He was sentenced to two

consecutive life terms plus twenty years. He noted a timely appeal to the Court of Special Appeals.

Armstead raised five issues before the Court of Special Appeals, but only one related to the admission of DNA evidence. He argued the trial court should not have admitted the DNA for two reasons. First, he claimed the trial court erred by not conducting a preliminary hearing, his proposed "inverse *Frye-Reed* hearing," to determine whether the evidence was reliable. Second, he argued the use of outmoded methods of analysis rendered the DNA evidence so unreliable as to violate due process.

The Court of Special Appeals affirmed the convictions in an unreported opinion. The intermediate appellate court held that the trial court did not err in refusing to conduct a preliminary hearing on the RFLP technique, stating that while "[t]he *reliability* of the RFLP testing procedure is always open to attack . . . the DNA profile's *admissibility* is incontestable." The Court of Special Appeals also held that the trial court did not err in refusing to exclude the DNA profile based on the statistical methods used because the evidence was admissible by statute. Finally, the intermediate appellate court held that Armstead's due process rights were not violated. We granted certiorari to consider the important questions presented.

II.

Petitioner raises five issues before this Court. At the outset, we note that the Petitioner does not question the reliability of the general principles underlying DNA profiling. Petitioner first argues that, despite the enactment of § 10-915, trial judges retain discretion to exclude DNA evidence if its probative value is substantially outweighed by its prejudicial effect; he therefore contends that the trial court erred by refusing to engage in such balancing. Second, Petitioner asserts that § 10-915 does not preclude the possibility of a preliminary hearing to challenge the reliability of DNA evidence, and that such an "inverse *Frye-Reed* hearing" should be held if new evidence comes to light that calls the reliability of a previously accepted scientific technique into question. Third, Armstead argues that population genetics statistics must meet the "general acceptance" standard articulated in *Reed v. State*, 283 Md. 374, 389, 391 A.2d 364, 372 (1978),[4] and that § 10-915 only established the admissibility of "raw" evidence of a DNA match. He concludes that if the *Frye-Reed* test had been applied to the statistical techniques used in this case, the product rule methodology would not have met the requisite "general acceptance" standard. Fourth, Armstead argues that because the laboratory error rate greatly

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[4]*Reed* adopted the "general acceptance" standard originally set forth in *Frye v. United States,* 293 F. 1013, 1014 (D.C. Cir. 1923), *overruled by Daubert v. Merrell Dow*, U.S. , 113 S. Ct. 2786, 2794, 125 L. Ed. 2d 469, 480 (1993); hereinafter, we shall refer to this as the *Frye-Reed* standard.

exceeded the probability of error due to random DNA matching, the statistics on the odds of random matching were meaningless. He reasons that the DNA evidence was therefore incapable of "proving identity" as required by the statute. § 10-915(b).

Finally, in addition to these statutory arguments, Petitioner asserts a constitutional challenge. He argues the statistical evidence on the possibility of a random DNA match was so unreliable, due to the laboratory error rate, the allegedly improper probability calculations, and the use of improper laboratory procedures, that his due process rights were violated.

The State contends that § 10-915 eliminated the need for trial courts to engage in *Frye-Reed* analysis, and eliminated the discretion of trial courts to engage in a case-by-case balancing of probative value against prejudicial effect. The State also argues that the statute contemplated the admission of both the basic evidence of a DNA match *and* the supporting statistical evidence because the statistics provide necessary contextual information, and because the statute explicitly refers to "allele frequency" data. § 10-915(b)(2)(v). Finally, the State argues that Armstead's due process arguments lack merit. The State contends that Petitioner's challenges to the statistical methodology, the laboratory procedures, and the laboratory error rate go to the weight of the evidence rather than its admissibility.

We will address some of the Petitioner's issues together,

consolidating the arguments to three questions:

> 1. How does § 10-915 impact the "gatekeeping" function of the trial court in screening DNA evidence?
>
> > (a) May the trial court conduct an "inverse *Frye-Reed* hearing" if the opponent of DNA evidence challenges its reliability?
> >
> > (b) May the trial court engage in a weighing exercise to determine if the probative value of DNA evidence is substantially outweighed by the prejudicial effect?
>
> 2. Does § 10-915 encompass population genetics statistics, in addition to the "raw" evidence of a DNA match?
>
> 3. Did the application of the product rule calculation, the rate of laboratory error, or the specific laboratory procedures used in this case render the resulting data so unreliable as to violate the Petitioner's due process rights?

We address each of these issues in turn below.

III.

In order to understand the legal issues presented, some scientific explanation on DNA testing is helpful. This information has already been presented in several Maryland cases, *see, e.g., Keirsey v. State*, 106 Md. App. 551, 665 A.2d 700 (1995); *Cobey v. State*, 80 Md. App. 31, 559 A.2d 391 (1989), *cert. denied,* 317 Md. 542, 565 A.2d 670 (1989), as well as cases from many other jurisdictions.[5] For that reason, the description that follows is

[5] For a more detailed discussion of the mechanics and history of DNA testing in forensics, *see generally* H. Lee et al., (continued...)

abbreviated.

A. History of the Forensic Use of DNA Profile Evidence

DNA profiling has been used for forensic purposes for nearly a decade. It was first used in a criminal case in the United Kingdom in 1985, OFFICE OF TECHNOLOGY ASSESSMENT, GENETIC WITNESS: FORENSIC USES OF DNA TESTING 8 (1990), and was subsequently adopted by the FBI in 1988. NRC REPORT at S-1 to S-2. Maryland's first appellate case addressing DNA profiling evidence was *Cobey v. State*, 80 Md. App. 31, 559 A.2d 391 (1989), *cert. denied*, 317 Md. 542, 565 A.2d 670 (1989). By 1990, DNA profiling had been used in over ten thousand cases in the United States. H. Lee et al., *DNA Typing in Forensic Science,* 15 AM. J. FORENSIC MED. & PATHOLOGY 269, 270 (1994); *see also* R. Chakraborty & K. Kidd, *The Utility of DNA Typing in Forensic Work*, 254 SCIENCE 1735, 1735 (1991). Since the technique was first introduced, the overwhelming majority of state courts that have

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[5](...continued)
*DNA Typing in Forensic Science,*15 AM. J. FORENSIC MED. & PATHOLOGY 269 (1994); COMMITTEE ON DNA TECHNOLOGY IN FORENSIC SCIENCE, NATIONAL RESEARCH COUNCIL, DNA TECHNOLOGY IN FORENSIC SCIENCE (1992) (Prepublication Manuscript) [hereinafter NRC REPORT]; OFFICE OF TECHNOLOGY ASSESSMENT, GENETIC WITNESS: FORENSIC USE OF DNA TESTS (1990). *See also United States v. Yee*, 134 F.R.D. 161, 169-73 (N.D. Ohio 1991), *aff'd sub nom United States v. Bonds*, 12 F.3d 540 (6th Cir. 1993); *State v. Vandebogart*, 139 N.H. 145, 652 A.2d 671, 675-77 (1994); *Com. v. Curnin*, 565 N.E.2d 440, 445-48 (Mass. 1991) (Appendix); *People v. Castro*, 545 N.Y.S.2d 985, 988-95 (Bronx County Ct. 1989).

considered DNA evidence have found it admissible.[6] *See Developments in the Law: Confronting the New Challenges of Scientific Evidence*, 108 HARV. L. REV. 1481, 1558 (1995).[7]

B. The Science of DNA

Deoxyribonucleic acid or DNA is the genetic material that provides the instructions for all human characteristics, from eye

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[6]Nearly all courts that have considered the admissibility of DNA evidence have found the general technique of DNA profiling reliable. *See Developments in the Law: Confronting the New Challenges of Scientific Evidence,* 108 HARV. L. REV. 1481, 1558 (1994). Some courts, however, have rejected DNA evidence because the population genetics component was held to be unreliable, *see, e.g., Com. v. Lanigan*, 413 Mass. 154, 596 N.E.2d 311, 314 (1992) (product rule method of calculating odds of a random DNA match not generally accepted, and evidence of a DNA match inadmissible without supporting statistics) (*Lanigan I*), *aff'd in part and rev'd in part*, 419 Mass. 15, 641 N.E.2d 1342 (1994) (ceiling principle method of calculating odds of a random DNA match now generally accepted and, therefore, DNA evidence admissible) (*Lanigan II*); *State v. Vandebogart*, 136 N.H. 365, 616 A.2d 483, 494 (1992) (product rule method of calculating odds of a random DNA match not generally accepted, and evidence of a DNA match inadmissible without supporting statistics), *modified on reh'g,* 139 N.H. 145, 652 A.2d 671 (1994) (ceiling principle method of calculating odds of a random DNA match now generally accepted and, therefore, DNA evidence admissible if supporting statistics offered that were calculated using ceiling principle), or because of errors in applying the profiling methods in a particular case. *People v. Castro*, 545 N.Y.S.2d 988 (Bronx County Ct. 1989).

[7]Even before it was used in forensics, DNA profiling had been used for a number of years for therapeutic purposes such as the diagnosis of hereditary medical diseases. Although there are significant distinctions between use of DNA analysis for forensic purposes versus therapeutic purposes, the longer experience with therapeutic DNA analysis has provided an opportunity to develop and refine the technique to its current level of consistency and reliability. *See* NRC REPORT, *supra*, at 2-2.

color to height to blood type. P. HARTMAN & S. SUSSKIND, GENE ACTION 2 (1965). Many types of cellular material carry DNA, including some types of blood cells, semen, and hair follicles. R. Lewontin & D. Hartl, *Population Genetics in Forensic DNA Typing,* 254 SCIENCE 1745, 1746 (1991). DNA is a "double helix" molecule, similar to a spiral staircase or a twisted rope ladder. Lee et al., *supra,* at 270. Each strand or "side" of the ladder is composed of four types of building blocks known as nucleotides, which can be connected in any order to form a DNA chain. *Id.* at 270-71. It is the sequence of the nucleotides that conveys the information, in effect "spelling out" the genetic instructions. G. BEADLE & M. BEADLE, THE LANGUAGE OF LIFE 193-94 (1966).

A strand of DNA contains an estimated 50,000 to 100,000 genes, each of which directs the construction of a specific protein. HARTMAN & SUSSKIND, *supra*, at 37. In addition to this "meaningful" DNA, the chain also includes "spacer" or "junk" DNA between the genes. The total amount of DNA composing all of an individual's genetic information includes over three billion individual nucleotides, and a typical gene for an individual characteristic may be made up of tens of thousands of nucleotides. Lee et al., *supra*, at 270.

While each individual's total DNA profile is unique, large segments of DNA are common to everyone. Out of the three billion nucleotides making up a complete DNA strand, there will likely be

about three million differences in the DNA sequence between two randomly selected individuals. NRC REPORT, *supra*, at S-7. Many of these differences will be found in the "spacer" DNA areas, particularly in the number of times a spacer sequence is repeated. These highly variable areas in the DNA strand are known as VNTR's, for "variable number of tandem repeats." Typically, a VNTR will contain between twenty and one hundred repeats of the same nucleotide sequence. *See* Lee et al., *supra*, at 272 (Fig. 4); Lewontin & Hartl, *supra*, at 1745-46.

In criminal investigations, DNA profiling is typically used to compare a suspect's DNA with a sample of DNA taken from the crime scene. DNA profiling does not compare every nucleotide of the suspect's DNA with every nucleotide of the sample DNA, but rather compares the two at selected sites that are likely to vary from person to person. It is possible, however, that sections of DNA taken from different people will match. To avoid this type of "random matching" error, comparisons are made at multiple sites or loci along the DNA chain. Typically, laboratories analyze four or five loci in conducting DNA comparisons, reducing the probability of random matches across all loci to a low level. *See* L. Roberts, *Fight Erupts Over DNA Fingerprinting*, 254 SCIENCE 1721, 1721-22 (1991).[8]

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[8]The only situation where two people should be found to have identical DNA is in the case of identical twins, NRC REPORT,

(continued...)

C. The Method of DNA Analysis

The basic process of DNA analysis is the same whether it is used for diagnostic or forensic purposes. The most widely used technique at present is restriction fragment length polymorphism (RFLP) analysis.[9] RFLP analysis involves three basic steps. First, a whole DNA strand is cut into smaller pieces using restriction enzymes, which are essentially chemical "scissors" designed to cut the DNA chain wherever a particular sequence of nucleotides is found. J. McKenna et al., *Reference Guide on Forensic DNA Evidence, in* FEDERAL JUDICIAL CENTER, REFERENCE MANUAL ON SCIENTIFIC EVIDENCE 282 (1994). The result is a mass of DNA fragments

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[8](...continued)
supra, at S-2, although siblings or other close relatives will also have substantial similarities in their DNA. *See B. Bockel et al., Likelihoods of Multilocus DNA Fingerprints in Extended Families,* 51 AM. J. HUM. GENETICS 554, 559 (1992).

[9]Although most cases to date have involved the RFLP method of DNA analysis, a newer method known as polymerase chain reaction (PCR) has also been developed. NRC REPORT, *supra*, at 1-8. This method is particularly useful in analyzing DNA where there is a very small evidence sample to be tested, because it utilizes the same method by which cells replicate DNA to "amplify" the quantity of DNA. *Id.* Alex Jeffreys, a pioneering DNA researcher, has proposed a digital technique for applying PCR that would eliminate some of the frequently challenged aspects of RFLP testing. *Id.* at 1-10. The PCR method, however, is subject to other types of technical error. *Id.* at 2-14 to 2-24.

Courts have already begun to evaluate the PCR method, and some have already held that the technique is generally accepted as reliable. *See, e.g., State v. Gentry*, 125 Wash.2d 570, 888 P.2d 1105, 1117 (1995); *People v. Lee* 212 Mich. App. 228, 537 N.W.2d 233 (1995).

of varying sizes. *Id.* The second step is to separate these fragments according to their size. Lee et al., *supra*, at 271-73. This is accomplished by passing a current through a gel medium containing the DNA. The fragments are negatively charged, so they will migrate toward a positive electrode. Their progress toward the electrode will vary depending on their size, and thus the fragments will spread out across the gel. *Id.* (Fig. 5). Using a process known as Southern Blotting, these fragments are transferred from the gel to paper and washed with a radioactive material that attaches itself to the DNA fragments. *Id.* at 273. When the paper is placed against a sheet of film, the radioactive material exposes areas of the film, producing a discernible pattern of dark bands. This "picture" is known as an autoradiograph. Each band on the autoradiograph represents a fragment of DNA. McKenna et al., *supra*, at 283. Finally, these banding patterns can be used for identification by comparing the banding pattern in the suspect's DNA with the pattern derived from DNA extracted from crime scene evidence. *Id.* at 283-84.

IV. Admissibility of DNA Match Evidence

A. General Principles of Statutory Construction

In Maryland, novel scientific evidence may become admissible in one of several ways. First, the evidence may be admitted by statute, if a relevant statute exists. *See* 5 L. McLain, MARYLAND EVIDENCE § 401.4(b), at 277-78 (1987). Second, the proponent can

prove that the evidence meets the *Reed* standard of "general acceptance" in the relevant scientific community. *Reed v. State*, 283 Md. 374, 381, 391 A.2d 364, 368 (1978) (quoting *Frye v. United States*, 293 F. 1013, 1014 (D.C. Cir. 1923)). This can be accomplished through expert testimony, judicial notice, or a combination of the two. *Goldstein v. State,* 339 Md. 563, 567, 664 A.2d 375, 376-77 (1995). In the present case, the first method applies because the Legislature, by enacting § 10-915, declared DNA profiling evidence reliable and admissible.

Section 10-915 provides, in pertinent part,

> (a) *Definitions*--
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> * * * * * *
>
> (2) "Deoxyribonucleic acid (DNA)" means the molecules in all cellular forms that contain genetic information in a patterned chemical structure of each individual.
> (3) "DNA profile" means an analysis that utilizes the restriction fragment length polymorphism analysis of DNA resulting in the identification of an individual's patterned chemical structure of genetic information.
>
> (b) *Purposes.* -- In any criminal proceeding, the evidence of a DNA profile is admissible to prove or disprove the identity of any person . . . .

The only condition the statute imposes on admission of DNA evidence relates to a discovery requirement, *viz,* information the proponent of the DNA evidence must provide to the opponent on request. §§ 10-915(b)(1)-(b)(2).[10]

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[10]Sections 10-915 b(1) and b(2) of the statute provide that (continued...)

The question we must consider is how to interpret the effect of § 10-915 on the traditional gatekeeping role of the trial court in determining the admissibility of DNA evidence. Petitioner raises two related questions in this regard, which we will analyze together. First, although Petitioner concedes that § 10-915 eliminates the need for a *Frye-Reed* hearing as a prerequisite to admission of DNA evidence, he contends that the Legislature merely intended to create a rebuttable presumption of admissibility. This interpretation, he argues, would allow the possibility for an opponent to challenge DNA evidence via an "inverse *Frye-Reed*" proceeding, in which the opponent would bear the burden of showing the DNA evidence to be unreliable. Second, Armstead contends that

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[10](...continued)
DNA profile evidence is admissible if the proponent:

> (1) Notifies in writing the other party or parties by mail at least 45 days before any criminal proceeding; and
> (2) Provides, if requested in writing, the other party or parties at least 30 days before any criminal proceeding with:
>
> (i) Duplicates of the actual autoradiographs generated;
> (ii) The laboratory protocols and procedures;
> (iii) The identification of each probe utilized;
> (iv) A statement describing the methodology of measuring fragment size and match criteria; and
> (v) A statement setting forth the allele frequency and genotype data for the appropriate data base utilized.

despite enactment of § 10-915, the trial court retains its discretion to balance the probative value of DNA evidence against its prejudicial effect.

Both of these issues are essentially matters of statutory interpretation. When construing a statute, our governing principle must be the Legislature's intent because, as we have consistently stated, the cardinal rule in statutory construction is to effectuate the Legislature's broad goal or purpose. *Gargliano v. State,* 334 Md. 428, 435, 639 A.2d 675, 678 (1994). The primary source of legislative intent is the language of the statute itself. *Rose v. Fox Pool*, 335 Md. 351, 359, 643 A.2d 906, 910 (1994). In reading the language, we apply common sense to avoid illogical or unreasonable constructions, *Frost v. State,* 336 Md. 125, 137, 647 A.2d 106, 112 (1994), and we ascribe to words their common meanings, unless the Legislature intended otherwise. *See Mustafa v. State,* 332 Md. 65, 73, 591 A.2d 481, 485 (1991).

If the language alone does not provide sufficient information on the Legislature's intent, then courts will look to other sources to discern the Legislature's purpose. *Gargliano,* 334 Md. at 436, 639 A.2d at 678. Alternatively, if the language itself is clear and unambiguous and comports with the apparent purpose of the statute, there may be no need to consider other sources of information to glean the Legislature's purpose. *Jones v. State,* 336 Md. 255, 261, 647 A.2d 1204, 1206-07 (1994). Because the

meanings of even common words may be context-dependent, however, we often proceed to consider other "external manifestations of legislative intent," *Tidewater v. Mayor of Havre de Grace,* 337 Md. 338, 347, 653 A.2d 468, 472 (1995), such as the amendment history of the statute, its relationship to prior and subsequent law, and its structure. *Shah v. Howard County,* 337 Md. 248, 255-57, 653 A.2d 425, 428-29 (1995); *Kaczorowski v. City of Baltimore*, 309 Md. 505, 515, 525 A.2d 628, 633 (1987).

B. Interpretation of § 10-915

1. Effect of the Statute on the Possibility of "Inverse Frye-Reed Hearings"

Applying the canons of statutory construction outlined above, we conclude that the notion of an "inverse *Frye-Reed* hearing" is inapposite when evidence is deemed admissible by statute. When the General Assembly has enacted legislation rendering evidence admissible, "the only way to contest the validity of the underlying principles involved would be to argue that the statutes violate one's right to due process of the law." L. McLain, MARYLAND EVIDENCE § 401.4(c), at 278 (1987 & 1994 Cum. Supp.). *See also* J. Murphy, MARYLAND EVIDENCE HANDBOOK § 1406(C), at 733 (2d ed. 1993 & 1995 Cum. Supp.).

In reaching this conclusion, as we have indicated, our touchstone is the intent of the Legislature in enacting § 10-915.

It is significant that the plain language of the statute explicitly states that DNA evidence "*is admissible* to prove . . . identity," § 10-915(b) (emphasis added), rather than using conditional language such as "may be admissible."[11] The General Assembly's choice of language alone, therefore, strongly suggests that the Legislature intended DNA profile evidence to be admitted without reevaluation of the technique's general reliability.

We next consider whether this reading of the language corresponds to the apparent purpose of the statute. The legislative history clearly demonstrates that the primary reason the General Assembly enacted § 10-915 was to render DNA evidence admissible without *Frye-Reed* analysis in each case. When the DNA legislation was initially proposed, the Senate Judicial Proceedings Committee's Report explicitly stated that "[t]he intent of the bill is to eliminate the necessity of holding a 'Frye-Reed' hearing to prove that the technique has gained general acceptance in the relevant scientific community." Senate Judicial Proceedings

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[11]By comparison, Virginia's statute governing the admissibility of DNA evidence provides that "DNA . . . testing shall be deemed to be a reliable scientific technique and the evidence of a DNA profile comparison *may be admitted* to prove or disprove the identity of any person." Va. Code Ann. § 19.2-270.5 (Michie 1995) (emphasis added). The conditional language of the Virginia statute has been interpreted to permit trial judges to continue to exercise their discretion to weigh the probative value of the DNA evidence against its prejudicial effect. *Satcher v. Com.*, 244 Va. 220, 421 S.E.2d 821, 835 (1992), *cert. denied*, U.S. , 113 S. Ct. 1319 (1993). *See infra* Section IV.B.2.

Committee, Report on House Bill No. 711, at 2 (1989). Before § 10-915 was enacted, DNA profile evidence was admissible only if the technique satisfied the *Frye-Reed* "general acceptance" test. *Reed*, 283 Md. at 389, 391 A.2d at 372. *See also Wheeler v. State*, 88 Md. App. 512, 524, 596 A.2d 78, 84 (1991); *Cobey*, 80 Md. App. at 38, 559 A.2d at 392. At that time, the issue was likely to be relitigated in each case. When the General Assembly enacted § 10-915 in 1989, it clearly intended to streamline this process. *See* Senate Judicial Proceedings Committee, Report on House Bill No. 711, at 2 (1989).[12]

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[12]Maryland is one of twelve states to enact legislation establishing the admissibility of DNA evidence in criminal cases. In addition to Maryland, the states that have enacted such legislation are: Alaska, 1995 Alaska Sess. Laws 7, §2 (codified at Alaska Stat. § 12.45.035 (1995)); Connecticut (Conn. Gen. Stat. § 54-86k (1995)), Delaware (Del. Code Ann. tit. 11, § 3515 (Michie Supp. 1994)), Indiana (Ind. Code Ann. § 35-37-4-13 (Burns 1994)), Louisiana (La. Rev. Stat. Ann. § 15:441.1 (West Supp. 1995)), Minnesota (Minn. Stat. Ann. §§ 634.25-634.26 (West Supp. 1995)), North Dakota (N.D. Cent. Code § 31-13-02 (Michie Supp. 1995)), Nevada (Nev. Rev. Stat. Ann. § 56.020 (Michie 1986 & Supp. 1993)), Tennessee (Tenn. Code Ann. §24-7-117 (Michie Supp. 1995)), Wisconsin (Wis. Stat. Ann. § 972.11 (West Supp. 1994)), and Virginia (Va. Code Ann. § 19.2-270.5 (Michie 1995)).

Four of the other eleven states--Alaska, Minnesota, Nevada, and Tennessee--have enacted statutes that explicitly state that probability estimates are also admissible. These provisions, however, take different forms. Tennessee's statute expressly states that "statistical population frequency evidence . . . is admissible in evidence to demonstrate the fraction of the population that would have the same combination of genetic markers as was found in a specific biological specimen." Tenn. Code Ann. § 24-7-117(c) (Michie Supp. 1995). Nevada's statute provides more generally that "[t]he opinion of any expert concerning results of blood tests may be weighted in accordance

(continued...)

The 1991 amendment of the DNA statute also illustrates the Legislature's confidence in the reliability of DNA evidence, because the amendment narrowed the potential arguments against admitting DNA evidence from general attacks on the methodology to specific attacks on the procedures used in the case at issue. The primary effect of the amendment was to expand the background information a proponent of DNA evidence would be required to give

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[12](...continued)
with evidence, if available, of the statistical probability of the alleged blood relationship." Nev. Rev. Stat. Ann. § 56.020 (Michie 1986 & Supp. 1993). Alaska's statute defines "DNA profile" to include "statistical population frequency comparisons of the patterned chemical structures." 1995 Alaska Sess. Laws 7, §2 (codified at Alaska Stat. § 12.45.013(b)(2)(B) (1995)).

Minnesota is unique because although its statute explicitly provides for the admission of statistics in support of DNA evidence, its courts have not uniformly admitted the statistics. The Minnesota statute provides that: "statistical population frequency evidence . . . is admissible to demonstrate the fraction of the population that would have the same combination of genetic markers as was found in a specific biologic specimen." Minn. St. Ann. § 634.26 (West Supp. 1995). In Minnesota, a line of cases culminating with *State v. Kim,* 398 N.W.2d 544 (Minn. 1987) had imposed limitations on the use of statistics because of the potentially "exaggerated impact on the trier of fact." *Id.* at 548. The Minnesota Supreme Court in *State v. Nielsen,* 467 N.W.2d 615 (Minn. 1991), questioned the legislature's authority to create an exception to the *Kim* doctrine for DNA evidence. *Id.* at 620. Relying on *Nielsen,* an intermediate appellate court again questioned the legislature's authority to render the statistics admissible in *State v. Alt,* 504 N.W.2d 38, 41 n.2 (Minn. App. 1993), *aff'd as modified*, 505 N.W.2d 72 (Minn. 1993). More recently, in *State v. Bloom,* 516 N.W.2d 159 (Minn. 1994), the Minnesota Supreme Court modified its position to permit expert witnesses to provide statistical evidence in DNA cases, but only under the ceiling principle approach proposed in the NRC report. *Id.* at 167.

to the opponent. Senate Judicial Proceedings Committee, Report on House Bill No. 1150, at 2 (1991). Initially, the duty to disclose background information on DNA testing offered in evidence only applied to the State, but the bill expanded this duty to apply to both the State and the defendant. *Id.* The proponent of DNA evidence now must provide copies of the autoradiographs, laboratory protocols, and additional information relating to the laboratory's statistical methods. § 10-915(b)(2)(i)-(v). The amendment also extended the notice requirement when DNA evidence is to be used from 15 days before trial to 45 days before trial. Senate Judicial Proceedings Committee, Report on House Bill No. 1150, at 2 (1991). In addition, courts are no longer required to ensure the presence of anyone in the chain of custody on demand.[13] Moreover, the proponent of DNA evidence is no longer required to submit *all* reports generated about the DNA analysis, nor *all* the laboratory's notes and photographs. *Id.* By providing the opponent with detailed, case-specific information on the DNA analysis and giving the opponent more time to evaluate the information before trial, the amendments also indicate the Legislature's intent to establish the general reliability and admissibility of the evidence, permitting the opponent to attack the weight of the evidence

[13]While the bill as originally proposed would have given parties the right to depose any witness testifying about the DNA evidence, this provision was eliminated prior to enactment. 1991 Maryland Laws ch. 631.

through cross-examination. House Bill No. 1150; 1991 Maryland Laws ch. 631, at 3447-49 (1991) (codified as amended at § 10-915).

Finally, as further evidence of the Legislature's intent, we turn to the preamble to the statute, which states that:

> [M]eans of identifying that unique DNA structure have been refined far beyond any previous means of human tissue analysis, to a level of scientific accuracy that approaches an *infinitesimal margin of error*[.]

1989 Maryland Laws ch. 430, Preamble, at 2893 (1989) (emphasis added). This statement plainly illustrates the Legislature's view that DNA evidence was sufficiently reliable to warrant elimination of the *Frye-Reed* hearings.[14]

We conclude that interpreting the statute to permit either traditional *Frye-Reed* hearings or the "inverse *Frye-Reed* hearings" proposed by the Petitioner would be contrary to the Legislature's intent. As stated in the Fiscal Note to House Bill 711, under the bill, "an extensive hearing process would not occur and, therefore, court proceeding costs would decrease." Division of Fiscal Research, Maryland General Assembly, Fiscal Note (Revised) on House

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[14]One of the amendments made to the DNA legislation after it was proposed and before its passage was to delete the words "unique" and "uniquely" throughout the bill whenever they were used to refer to an individual's DNA pattern. 1989 Maryland Laws ch. 430, § 1, at 2893 (1989) (codified as amended at § 10-915). This alteration demonstrates that the Legislature was aware of the possibility that an individual's DNA pattern was not unique, and thus recognized the potential for random matching. Nevertheless, the Legislature unequivocally deemed DNA profiling reliable.

Bill No. 711, at 1 (May 19, 1989). This statement is significant because it demonstrates that the Legislature intended to eliminate *any* extensive hearings, not merely to change the nature of the hearings by shifting the burden from the State to the defendant. The Legislature enacted § 10-915 to save time and money. Merely shifting the burden to defendants to prove DNA evidence unreliable, rather than requiring the State to prove it reliable, would not effectuate this purpose. Valuable resources and great time expenditures would still be required because both types of hearings are resource-intensive procedures which require costly and time-consuming expert testimony.[15] This the Legislature sought to eliminate. We therefore conclude that the statute eliminates not only traditional *Frye-Reed* hearings, but also "inverse *Frye-Reed* hearings."

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[15]The NRC Report estimated that states would spend millions of dollars on forensic DNA evidence, including expenditures to provide experts to testify for the State, to fund testing and experts for indigent defendants, and to maintain and upgrade DNA databases storing the profiles of convicted felons. NRC REPORT, *supra*, at 6-18 to 6-19.

2. The Effect of § 10-915 on the Discretion of the Trial Court to Weigh Probative Value Against Prejudicial Effect

Petitioner's second argument, that the trial court retains discretion to balance the probative value of DNA evidence against its prejudicial effect is also without merit. As one court observed in *United States v. Yee*, 134 F.R.D. 161 (N.D. Ohio 1991), *aff'd sub nom United States v. Bonds*, 12 F.3d 540 (6th Cir. 1993), the *Frye* test was designed to serve the same purpose as the trial judge's discretionary balancing of probative value against prejudice:

> The *Frye* doctrine developed . . . out of the same concerns that led to the adoption of Rule 403 [providing the authority to weigh probative value against prejudicial effect]: namely, the concern that lay jurors might be misled by testimony that was unfairly prejudicial, confusing, or misleading.

Id. at 212 (citing *United States v. Brown*, 557 F.2d 541 (6th Cir. 1977)). By enacting § 10-915 and thereby eliminating *Frye-Reed* hearings, the General Assembly legislatively determined that the probative value of DNA outweighs any prejudicial effect. The Legislature, in doing so, implicitly rejected Petitioner's general arguments that DNA evidence is inherently prejudicial, the argument that the "aura of mystic infallibility" associated with DNA overshadows all other evidence, or the argument that highly technical evidence is "overwhelming" to juries. Except for constitutional challenges, therefore, generalized attacks on DNA

testing are now precluded.

Petitioner also argues that use of the language "is admissible" in § 10-915 rather than mandatory language such as "shall be admitted" indicates that the Legislature intended to permit judges to continue to exercise discretion to exclude DNA evidence in some situations. We have considered the Legislature's choice of language above, *see supra* Section IV.A, and we conclude that the words "is admissible" have eliminated the discretion of the trial court to weigh probative value against prejudicial effect.

Although we find that § 10-915 has eliminated some of the trial court's gatekeeping responsibilities with regard to DNA evidence, we emphasize that trial courts still exercise an important function in determining whether DNA evidence is logically relevant to the case at hand. As we noted in *Reed*, there is an important distinction between the trial judge's discretion to evaluate relevancy as opposed to reliability:

> The question of the reliability of a scientific technique or process is unlike the question, for example, of the helpfulness of particular expert testimony to the trier of facts in a specific case. The answer to the question about the reliability of a scientific technique or process does not vary according to the circumstances of each case. It is therefore inappropriate to view the threshold question of reliability as a matter within each trial judge's individual discretion.

Reed, 283 Md. at 381, 391 A.2d at 368. *See also Haines v.*

Shanholtz, 57 Md. App. 92, 98, 468 A.2d 1365, 1369 (1984), *cert. denied*, 300 Md. 90, 475 A.2d 1201 (1984).[16]

While ordinarily DNA evidence will be admissible, the trial judge retains the discretion to exclude DNA evidence if errors in the laboratory procedures render it so unreliable that it would not be helpful to the trier of fact. *See Jackson v. State,* 92 Md. App. 304, 323, 608 A.2d 782, 791 (1992), *cert. denied,* 328 Md. 238, 614 A.2d 84 (1992). We recognize that courts in other jurisdictions

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[16]Paternity testing cases also serve to clarify the proper role of the trial court in determining relevance. For example, in *Haines v. Shanholtz*, 57 Md. App. 92, 468 A.2d 1365 (1984), *cert. denied,* 300 Md. 90, 475 A.2d 1201 (1984), as here, the Legislature enacted a statute governing admissibility of scientific evidence. Md. Code (1984, 1991 Repl. Vol., 1995 Cum. Supp.) § 5-1029(e)(ii) of the Family Law Article. In *Haines,* however, the evidence at issue was blood testing. The statute provided that "test results may be received in evidence in cases where . . . the probability of the alleged father's paternity is at least 97.3 percent." *Id.* at 96, 468 A.2d at 1366-67. Under this statute, the Court of Special Appeals held that:

> [T]he trial court should not have engaged in a determination of scientific acceptance of genetic testing for establishing paternity . . . The legislative intent is clear--genetic testing is valid, subject to cross-examination of those responsible for performing and evaluating the tests. The trial judge has the discretion of admitting testimony that may have a bearing on the *weight* of the testimony offered . . . but not, by reason of the statute, as to the admissibility *vel non* of genetic testing to establish paternity.

Id. at 97-98, 468 A.2d at 1367 (emphasis in original). *See also Kammer v. Young*, 73 Md. App. 565, 535 A.2d 936 (1988), *cert. denied,* 488 U.S. 919 (1988).

have adopted differing views regarding whether challenges to the laboratory procedures used in a specific case go to the admissibility of DNA evidence or merely to its weight. *Compare United States v. Martinez,* 3 F.3d 1191, 1197-98 (8th Cir. 1993), *cert. denied*, U.S. , 114 S. Ct. 734 (1993), *with United States v. Jakobetz,* 955 F.2d 786, 800 (2d Cir. 1992), *cert. denied,* U.S. , 113 S. Ct. 104 (1992). *See also United States v. Two Bulls,* 918 F.2d 56 (8th Cir. 1990), *vacated and dismissed as moot*, 925 F.2d 1127 (8th Cir. 1991). Some courts, following the line of cases beginning with the trial court decision in *People v. Castro,* 545 N.Y.S.2d 985 (Bronx County Ct. 1989), require adherence to accepted DNA protocols as a predicate for admissibility,[17] *see,*

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[17]The court in *Castro* articulated a three-part test for admissibility of DNA evidence:

> *Prong I.* Is there a theory, which is generally accepted in the scientific community, which supports the conclusion that DNA forensic testing can produce reliable results?
>
> *Prong II.* 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?
>
> *Prong III.* Did the testing laboratory perform the accepted scientific techniques in analyzing the forensic samples in this particular case?

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

(continued...)

e.g., State v. Houser, 241 Neb. 525, 490 N.W.2d 168, 181 (1992); *Ex Parte Perry*, 586 So.2d 242, 250 (Ala. 1991), while others have concluded that case-specific errors in the laboratory procedures should ordinarily be evaluated by the factfinder in determining the weight of the evidence. *See, e.g., United States v. Chischilly*, 30 F.3d 1144, 1152-53 (9th Cir. 1994), *cert. denied*, U.S. , 115 S. Ct. 946 (1995); *United States v. Bonds,* 12 F.3d 540, 561 (6th Cir. 1993); *People v. Wesley*, 83 N.Y.2d 417, 633 N.E.2d 451, 458 (1994); *Fishback v. People*, 851 P.2d 884, 893 (Colo. 1993); *State v. Cauthron*, 120 Wash. 2d 879, 846 P.2d 502, 507 (1993); *People v. Mohit*, 579 N.Y.S.2d 990, 992 (Westchester County Ct. 1992). We believe the better approach is generally to treat individualized errors in application of the DNA technique as matters of weight, but to permit trial judges discretion to exclude DNA evidence if such errors were made in the course of testing that the evidence would not be helpful to the factfinder.[18]

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[17](...continued)

[18]This approach is supported by the NRC Report, which stated that:

> The validity of [the] assumption . . . that the analytical work done for a particular trial comports with proper procedure . . . can be resolved only case by case and is always open to question, even if the general reliability of DNA typing is fully accepted in the scientific community. The DNA evidence should not be admissible if the

(continued...)

In order to resolve the issues presented in this case, we must first distinguish Petitioner's general challenges to DNA testing from his particularized challenges to the procedures used in his case because, as we have indicated, his general challenges to the DNA testing methodology have been precluded by statute, while his specific challenges remain within the trial court's discretion. We conclude that two of Petitioner's contentions---his challenge regarding the use of the product rule and his challenge regarding the rate of laboratory error as compared to the odds of random matching---are general challenges, and as such, they are precluded.

A constitutional challenge to the statute or its application stands on a different footing from other generalized challenges to DNA evidence. The trial court always retains the authority to consider constitutional challenges to the statute or its

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[18](...continued)

> proper procedures were not followed. Moreover, even if a court finds DNA evidence admissible because proper procedures were followed, the probative force of the evidence will depend on the quality of the laboratory work.

NRC REPORT, *supra*, at 6-4.

In determining whether an alleged error in DNA testing constitutes the type of error that warrants exclusion of DNA evidence, trial courts must distinguish mere *measurement error*, which is inherent in any scientific procedure, from deviations from accepted testing procedures. For example, contamination or degradation of the DNA sample constitutes the type of error that warrants exclusion.

application. We review the decision of Petitioner's due process claim in Section VI, *infra*.

Petitioner attempts to raise one objection to the DNA testing methods as applied in his specific case: the presence of "shadow banding" in the autoradiographs.[19] Shadow bands are "extra" bands

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[19]The Petitioner also raised another challenge, *i.e.*, that the differences in the results obtained by the FBI testing laboratory and Cellmark Diagnostics rendered the test results in his case so unreliable that they lacked probative value. The specific difference was that the FBI autoradiograph showed a double band at one locus, while Cellmark's autoradiograph only showed one band at that locus. The presence of two bands at one locus generally indicates that a person is heterozygous, which means they have two different alleles or forms of a particular gene. G. BEADLE & M. BEADLE, THE LANGUAGE OF LIFE 54-66 (1966). For example, if a person has one gene for blue eyes and another gene for brown eyes, he or she is heterozygous for the eye color gene. By comparison, the presence of only one band may indicate that a person is homozygous, or that they have two copies of the same allele for a particular gene. *Id.* Absent a rare genetic mutation, the same person can not be both homozygous and heterozygous for a given gene, since this is determined at conception, when each parent contributes one allele of each gene. *Id.* at 65.

As the experts explained in the pre-trial hearing, however, this discrepancy can be accounted for by differences in the testing conditions used by the two laboratories. The FBI expert, Dr. Dwight Adams, and the Cellmark expert, Dr. Charlotte Word, attributed the difference to the likelihood that low-molecular weight bands may run off the bottom of the gel, causing only one band to appear at a locus where two bands would normally be found. Dr. Word noted that Cellmark's procedures typically yielded larger fragments, while the FBI's system typically yielded smaller fragments. As a result, the Cellmark method would be more likely to show very large bands, which would often be lost using the FBI methods, while the FBI system would be more likely to show very small bands.

Although Armstead frames this argument as one that is specific to the DNA evidence in his case, we believe it is really

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that appear in one autoradiograph but not another, even though both are believed to be derived from the same source. Shadow bands may either indicate that the two DNA samples do not match, or they may be due laboratory error, such as excessive cutting action by the restriction enzymes, a phenomenon known as "star activity." NRC REPORT, *supra*, at 2-9 to 2-10.

Although Petitioner raised the issue of shadow banding before the trial court as part of his due process challenge, however, he did not argue that the trial court retained its discretion under the statute to exclude the DNA evidence due to the shadow banding. Therefore we shall not reach the issue in this appeal. Md. Rule 8-131(a).

To summarize, we hold that § 10-915 precludes generalized challenges to the admissibility of DNA evidence, except for constitutional challenges. It therefore eliminates both traditional *Frye-Reed* or "inverse *Frye-Reed*" hearings and individualized balancing of probative value against prejudicial effect. The statute does, however, permit case-specific challenges

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[19](...continued)
a general attack on the inherent variability of DNA analysis. All DNA testing will vary slightly depending on the type of probe, the restriction enzyme, the gel, the amount of time the experiment "runs," etc. General attacks on these procedures are precluded under § 10-915.

to the manner in which a particular test was conducted. Although these particularized challenges ordinarily will go to the weight of the evidence rather than its admissibility, the trial judge retains discretion to exclude evidence if it is so unreliable that it would not be helpful to the factfinder. *See, e.g., Reed*, 283 Md. at 389, 391 A.2d at 372 ("Testimony based on a technique which is found to have gained 'general acceptance . . .' *may* be admitted into evidence, but only if a trial judge also determines in the exercise of his discretion, as he must in all other instances of expert testimony, that the proposed testimony will be helpful to the jury, that the expert is properly qualified, etc.").

Accordingly, we hold that the trial judge did not abuse his discretion in declining to conduct an "inverse *Frye-Reed* hearing" and in refusing to balance the probative value of DNA evidence against its prejudicial effect.

V. Admissibility of Population Genetics Statistics

The next issue we must consider is whether population genetics statistics are admissible under § 10-915. Again, to resolve the legal issue, it is helpful to have a basic understanding of the science of population genetics.

A. The Scientific Debate Regarding the Use of Population Genetics Statistics

For each genetic characteristic, there may be two or more

variations or forms of the controlling gene, which are called alleles. NRC REPORT, *supra*, at 1-3. Each parent contributes one copy of each gene, so every individual has two copies or alleles of each gene. *Id.* For two-allele genes, *i.e.*, genes with only a "form A" and a "form B," an individual may end up with one of three possible combinations: AA, AB, or BB. Each combination of alleles is known as a genotype. *Id.* at 1-5 (Fig. 1-3). RFLP analysis examines a number of different alleles from a single strand of DNA. *Id.*

The first step in statistically analyzing the results of RFLP testing is to determine the frequency of occurrence of each allele tested in the general population. *Id.* at 3-2. In the case of a two-allele gene, form A may occur in 30% of the population, while form B occurs in 70% of the population. Therefore, the fact that an individual has form A of the allele is not, in itself, very informative because there is a 30% chance that form A would be found in a random member of the population.

Let us assume, however, that three different loci are tested. The alleles for each locus are A1 and B1, A2 and B2, and A3 and B3, respectively. Further assume that the allele frequencies for the general population are 10% for all the "A" alleles, and 90% for all the "B" alleles. If the suspect's DNA is found to include alleles A1, A2, and A3, the probability of a random match with this profile can be calculated by multiplying the probability of a random

individual having allele A1 times the probability of having A2 times the probability of having A3, or 10% times 10% times 10%, which equals 0.1%.[20] *See* R. Lempert, *The Suspect Population and DNA Identification,* 34 JURIMETRICS J. 1, 1-2 n.3 (1993). By increasing the number of loci tested, this probability of random matching can be reduced further, so that if five alleles were tested, the probability of a random match would be only 0.001%, or one in one hundred thousand. *See supra* note 20. In actual practice, the probability of random matching is reduced even further by choosing highly variable areas of the DNA with dozens of different alleles, so that individual allele frequencies will be very low. Chakraborty & Kidd, *supra*, at 1735, 1736.

There are at least two significant potential problems in calculating the probability of a random DNA match as outlined above. The first question is how to combine the probability of random matching for each allele to come up with an overall probability of random matching across all alleles. The second question is how to select the proper reference group to be used to calculate the general allele frequency in the population. The essence of this query is whether the general population may be

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[20] In reality, two alleles would be identified at each locus tested. For example, at locus one, a person could be found to have one of three "genotypes" or combinations of alleles: A1/A1; A1/B1, or B1/B1. NRC REPORT, *supra*, at 1-5 (Fig. 1-3). For simplicity, however, our hypothetical probability calculations use only one allele at each locus.

used, or whether there is enough difference in allele frequency across racial and ethnic population subgroups to require more specific subpopulation frequencies to be used.[21] We note that although there was significant debate across the country in both the scientific and legal communities concerning these issues, *compare* Lewontin & Hartl, *supra, with* Chakraborty & Kidd, *supra,* this controversy has largely been resolved by recent scientific studies. *See, e.g.,* B. Budowle et al., *The Assessment of Frequency Estimates of Hae III-Generated VNTR Profiles in Various Reference Databases,* J. FORENSIC SCI. 319, 349 (1994); U.S. DEP'T OF JUSTICE, VNTR POPULATION DATA: A WORLDWIDE STUDY (1993); B. Devlin & N. Risch, *A Note on Hardy-Weinberg Equilibrium of VNTR Data by Using the Federal Bureau of Investigation's Fixed-Bin Method,* 51 AM. J. HUM. GENETICS

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[21]A third question has been raised somewhat less often than the two discussed above regarding DNA evidence. This issue relates to the mechanics of how the visual pattern produced by RFLP analysis is translated into allele assignments. As described above, the variable areas of DNA tested in DNA profiling, VNTR's, may contain between 20 and 100 repeats of the same nucleotide sequence. One profile may have a 29-repeat segment, while another may have a 35-repeat segment. DNA profiling, however, is not sufficiently precise to identify small differences in the number of repeats; therefore, a process known as "binning" is used to sort the differing lengths of DNA fragments into categories. Each category is interpreted to represent a different allele, although in reality, each may contain several alleles: for example, one "bin" may include 26-repeat, 27-repeat, and 28-repeat segments because their lengths are not sufficiently different to distinguish them. *See, e.g.,* L. Mueller, *Population Genetics of Hypervariable Human DNA*, *in* FORENSIC DNA TECHNOLOGY 56 (1992). Several conservative assumptions have been incorporated in the binning process, however, which have resolved most theoretical objections, although concerns about binning have not completely disappeared.

549 (1992); B. Devlin & N. Risch, *Ethnic Differentiation at VNTR Loci, with Special Reference to Forensic Applications,* 51 AM. J. HUM. GENETICS 534, 545-47 (1992).

Most of the controversy over use of DNA evidence has focused on the first question, *i.e.*, how to combine the probabilities of random matching across all alleles. The hypothetical allele frequency calculations described above rely on a probability principle known as the "product rule." Stated generally, the product rule means that the probability of two events occurring together is equal to the probability that event one will occur multiplied by the probability that event two will occur. R. FREUND & W. WILSON, STATISTICAL METHODS 62 (1993). The classic illustration is coin tossing; the probability of finding "heads" on two successive coin tosses is equal to the probability of heads on the first toss, 50%, times the probability of heads on the second toss, 50%, equalling 25%. R. JOHNSON, ELEMENTARY STATISTICS 143 (4th ed. 1984).

The product rule is valid if the individual events are independent, *i.e.*, if the outcome of the first event does not impact the outcome of the second event. FREUND & WILSON, *supra,* at 62. In the coin toss example, this means that the outcome of the first coin toss does not affect the outcome of the second coin toss, which is a valid assumption. *Id.* By comparison, assume we wish to calculate the probability of having both a checking account and a loan from a particular bank. This is an example of non-

independent or linked events. JOHNSON, *supra,* at 144. We can not calculate the probability of having both a loan and a checking account at the same bank by multiplying together the individual probabilities under the product rule because a person is more likely to obtain a loan from the bank where he maintains a checking account. *Id.* To illustrate nonindependence as it applies to human characteristics (although not genetic characteristics), assume we wish to determine the probability a man will have both a beard and a moustache. Also assume that the probability of having a beard is 1/20, and the probability of having a moustache is 1/10. It would be incorrect to infer that the probability of having both a beard and a moustache, applying the product rule, is 1/200, because it is likely that these are non-independent events; men who have beards are probably more likely than others to also have moustaches. *See People v. Collins,* 66 Cal. Rptr. 497, 503 & n.15, 438 P.2d 33, 39 & n.15 (1968).[22]

The legal and scientific debate regarding DNA evidence mainly revolved around whether or not the product rule could be applied to genetic testing. L. Roberts, *Fight Erupts Over DNA Fingerprinting*, 254 SCIENCE 1721, 1723 (1991); *see also* J. McKenna et al., *Reference Guide on Forensic DNA Evidence, in* REFERENCE MANUAL ON SCIENTIFIC EVIDENCE

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[22]For a thorough discussion of independent and non-independent events, see D. STIRZAKER, ELEMENTARY PROBABILITY 22-30 (1994). Stirzaker provides a useful genetic example at pages 29-30. *Id.*

300 (1994). In the past, population geneticists and other scientists disagreed over whether the probability of possessing one allele was really independent from the probability of possessing another allele, and over the importance of any such differences. *Compare* Chakraborty & K. Kidd, *supra*, *with* Lewontin & Hartl, *supra*. *Theoretically,* truly independent distribution of individual alleles in the population requires completely random mating across racial and ethnic divisions, under a genetic principle known as Hardy-Weinberg equilibrium.[23] Lewontin & Hartl, *supra*, at 1746-47; Chakraborty & Kidd, *supra*, at 1736. Since it is generally acknowledged that the population has not reached such a state of equilibrium at present, some scientists hypothesized that there might be significant substructuring in the population which could cause considerable variation in the allele frequency across subpopulations. Lewontin & Hartl, *supra,* at 1747; L. Mueller, *Population Genetics of Hypervariable Human DNA*, *in* FORENSIC DNA TECHNOLOGY 60 (1992). There was, however, no empirical data to support this theory. Chakraborty & Kidd, *supra*, at 1737-38.

In 1992, the National Research Council issued a report on forensic DNA testing to attempt to resolve this dispute. NRC REPORT, *supra*. Although the report recommended using a conservative

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[23]The terms "linkage equilibrium" and "gametic phase balance" are related to the concept of Hardy-Weinberg equilibrium, although they are not interchangeable. All reference a theoretical state of random mating across racial and ethnic lines. Lewontin & Hartl, *supra*, at 1746-47.

modification of the product rule known as the ceiling principle, it did not ultimately reject the product rule. *Id.* at S-11. Instead, it merely suggested that until data could be collected to confirm or refute the existence of significant population substructuring effects, the interim approach should be to incorporate several conservative assumptions into the product rule calculation. *Id.* at S-11 to S-12. The effect of these conservative assumptions is to maximize the likelihood of random matches, thus decreasing the power of the DNA results to some extent.[24]

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[24]The ceiling principle "assumes the worst" about the amount of variation in allele frequencies across subpopulations. Under the product rule, the odds of a random match at one allele are determined by comparison with the frequency of occurrence of that allele in the population. Therefore, if a particular allele that shows up in the suspect's sample occurs in 1% of the population, there is a 1% chance of a random match.

Suppose, instead, that the allele in question occurs in a low percentage of Caucasians, but in a much higher percentage of Hispanics. The ceiling principle proponents at one point suggested that, in case such variability existed (although data did not then exist to confirm or refute this), we should assume a much higher maximum frequency than is likely, so that the possibility of error due to a random match is minimized. NRC REPORT, *supra*, at 3-10 to 3-12. The NRC report recommended using an "interim" population allele frequency of 10%, to be replaced by a figure of 5% once preliminary data was collected. *Id.* at 3-21. These rates were considerably higher than the likely maximum allele frequency for any subgroup, based even on then-existing data. *See, e.g.,* B. Devlin et al., *Statistical Evaluation of DNA Fingerprinting: A Critique of the NRC's Report*, 259 SCIENCE 748, 749 (1993).

Other than incorporating these maximum allele frequencies, the product rule would still be applied as discussed above. *See, e.g.,* NRC REPORT, *supra*, at S-11 to S-12.

While the NRC report did not definitively resolve the issue, however, the debate over the product rule essentially ended in 1993, with the announcement in the scientific journal NATURE that the "DNA fingerprinting wars are over." E. Lander & B. Budowle, *DNA Fingerprinting Dispute Laid to Rest*, 371 NATURE 735, 735 (1994). Eric Lander, formerly a vociferous opponent of use of the product rule, was one of the authors heralding this shift in scientific opinion.[25] *Id.* While a small number of scientists still advocate very conservative treatment of DNA analysis until more data is collected, *see, e.g., More on DNA Typing Dispute,* 373 NATURE 98-99 (1995), the empirical data collected thus far has indicated that the population substructuring that currently exists does not result in forensically significant variation in allele frequencies across

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[25]Emphasizing the convergence of scientific opinion regarding population genetics statistics, Lander and Budowle note in their article that:

> As co-authors, we can address these questions in an even-handed manner. B.B. [Bruce Budowle] was one of the principal architects of the FBI's DNA typing programme, whereas E.S.L. [Eric S. Lander] was an early and vigorous critic of the lack of scientific standards and served on the NRC committee. In a world of soundbites, we are often pegged as, respectively, a "proponent" and an "opponent" of DNA typing. Such labels greatly oversimplify matters, but it is fair to say that we represent the range of scientific debate.

Lander & Budowle, *supra,* at 735.

population subgroups.[26] *See* Lander & Budowle, *supra,* at 736; see also B. Devlin & N. Risch, *A Note on Hardy-Weinberg Equilibrium of VNTR Data by Using the Federal Bureau of Investigation's Fixed-Bin Method,* 51 AM. J. HUMAN GENETICS 549 (1992); B. Budowle et al., *The Assessment of Frequency Estimates of Hae III-Generated VNTR Profiles in Various Reference Databases,* 39 J. FORENSIC SCI.319 (1994). Ultimately, the studies have generally concluded that use of the ceiling principle is unnecessary:

> [T]he data *do not support the need for alternate procedures, such as the ceiling principle approach* (NRC Report 1992), for deriving for deriving statistical estimates of DNA profile frequencies.
>
> Estimates of the likelihood of occurrence of a DNA profile using each of the major population group databases (*e.g.,* Caucasian and Black) provide a greater range of frequencies than would estimates from subgroups of a major population category. *Comparisons across major population groups provide reasonable, reliable, and meaningful estimates of DNA profile frequencies without*

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[26]While Hartl and Lewontin continue to advocate conservative treatment of DNA evidence, their attack on population genetics statistics has shifted; Lewontin, for example, recently asserted that "juries are no more capable of understanding probability statements than they are of interpreting any other piece of highly technical information." R. Lewontin, Letter, NATURE 398 (1994); *see also* D. Hartl, Letter, 372 NATURE 398-99 (1994). This position has been subject to considerable criticism by other scientists. For example, in a recent response to Lewontin's comment, the author stated "[t]he continued existence of a Flat Earth Society and the increasing popularity of Creationism demonstrate that it is never possible to convince every individual of the validity of a scientific theory," and noted how "a tiny, vocal minority with access to media outlets can attempt to sway public opinion against generally accepted medical and scientific opinions." C. Strom, Letter, 373 NATURE 98-99 (1995).

> *forensically significant consequences.*

VNTR POPULATION DATA STUDY, *supra,* at 6 (emphasis added). Similarly, another study concluded that:

> Subdivision, either by ethnic group or by U.S. geographic region, within a major population group does not substantially affect forensic estimates of the likelihood of occurrence of a DNA profile. . . . Estimated frequencies among regional groups and several subgroups of a major population category are similar. . . . The most appropriate approach, therefore, is to estimate the likelihood of occurrence of a particular DNA profile in each major group. . . . [B]ased on empirical data, *there is no demonstrable need for employing alternative approaches, such as the ceiling principle, to derive statistical estimates. VNTR frequency data from major population groups provide valid estimates of DNA profile frequencies without significant consequences for forensic inferences.*

Budowle et al., *supra,* at 349 (emphasis added). In recent cases, courts considering the admissibility of DNA evidence have cited the growing list of scientific publications refuting the Hartl and Lewontin theory and supporting the continuing validity of the product rule. *See, e.g., People v. Smith*, 49 Cal. Rptr. 2d 608, 613-15 & n.15 (Ct. App. 1996); *People v. Marlow*, 41 Cal. Rptr. 2d 5, 32-33 (Ct. App. 1995), *cert. granted*, 1995 Cal. LEXIS 4583 (July 20, 1995) (No. G013492); *People v. Soto*, 35 Cal. Rptr. 2d 846, 855-56 (Ct. App. 1994), *cert. granted*, 890 P.2d 1115 (Cal. 1995).[27]

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[27] The dissent apparently dismisses the importance of the FBI study in dispelling the controversy regarding the product rule versus the ceiling principle. *See* dissenting op. at 22-23 & (continued...)

In addition to the controversy between the product rule and the ceiling principle, however, scientists have also pointed to problems in the selection of a reference database. Lewontin & Hartl, *supra*, at 1746. *See also Com. v. Curnin*, 409 Mass. 218, 565 N.E.2d 440, 444 & n.11 (1991). In the hypothetical calculation described above, *see supra* pages 31-32, we assumed that form A of the gene occurred in 30% of the population, while form B of the gene occurred in 70% of the population. In reality, however, it is difficult to determine the population frequency of a given allele. First, the relevant population must be defined. Lewontin & Hartl, *supra*, at 1746. If allele frequencies vary substantially across ethnic and racial population subgroups, then it may be necessary to base the population frequency on a subgroup corresponding to the suspect's ethnic or racial category. *Id.* at 1747-49. If the suspect is Hispanic, therefore, the most conservative way to proceed is to use a Hispanic population group to determine the allele frequency.[28] Even within the Hispanic category, however,

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[27](...continued)
n.7. Contrary to the dissent's view, however, courts that have addressed the admissibility of population genetics subsequent to the FBI's VNTR study have recognized that current scientific data does not support the need to apply either the ceiling principle or the modified ceiling principle. *See, e.g., Smith*, 49 Cal. Rptr. 2d at 613-14; *Marlow*, 41 Cal. Rptr. 2d at 32-33.

[28]This approach, however, also presents problems, because

> [t]o use the specific ethnic background of the suspect (which may be impossible to

(continued...)

there is substantial potential for variation in allele frequencies, *i.e.*, from Hispanics who are mainly of Indian descent versus Hispanics mainly of European descent. *Id.* at 1749 ("Because of the extreme heterogeneity among 'Hispanics' and among 'native Americans,' it is doubtful whether any reference population could be defined that would be reliable in a forensic context."). *See also* Lempert, *supra*, at 2.

Further complicating the issue, even assuming one can determine the proper population database to draw from, the allele frequency must still be determined. This requires obtaining sample DNA profiles from some significant number of people, ranging from several hundred to several thousand. Scientists disagree over the appropriate minimum number of profiles that should be used to make a database meaningful. *See* Devlin et al., *supra*, at 749; *see also People v. Soto*, 35 Cal. Rptr. 2d 846, 852 n.15 (Ct. App. 1994), *cert. granted,* 890 P.2d 1115 (Cal. 1995). Moreover, the more

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[28](...continued)
> define) would presuppose that he or she be the true perpetrator. However, if the true perpetrator were known *a priori,* there would be no need for statistical estimates. Furthermore, if a particular subgroup was chosen as the reference database, for the majority of cases this would insinuate that a member of one subgroup is a more likely source of the crime scene evidence.

Budowle et al., *supra,* at 320. The authors therefore conclude that "[s]ince the ethnicity of those people who are potential perpetrators rarely, if ever, is known, statistical estimates must be based on some sort of general population database." *Id.*

refined the subgroup analysis becomes, the smaller the subset of the total database that can be used, exacerbating the database size problem. As a result, if a database of several thousand profiles is limited, for statistical analysis purposes, to only those profiles belonging to Indian-descended Hispanics, this may reduce the reference database to only a few dozen profiles.[29]

Resolution of the product rule versus ceiling principle debate has, however, also ameliorated the database selection problem. Since the majority of scientists now believe that the effects of population substructuring are relatively insignificant, it has become unnecessary to develop data for very small population subgroups. *See generally* VNTR POPULATION DATA STUDY, *supra*; E. Lander & B. Budowle, *supra*; Chakraborty et al., *supra*; Budowle et al., *supra*. *See also* Lempert, *supra*, at 3.[30]

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[29]In the present case, population genetics statistics were calculated using a Caucasian database, a Hispanic database, and an African American database. The odds of one in 800,000 and one in 480 million referred to in this appeal were calculated using the African American database. The database consisted of approximately 250 persons from the Detroit metropolitan area.

[30] Lempert argues that while population substructuring is no longer a significant concern in most cases, there are still caveats regarding the use of DNA evidence. R. Lempert, *The Suspect Population and DNA Identification,* 34 JURIMETRICS J. 1 (1993). For example, he suggests that the odds of random matches between the suspect DNA and DNA taken from the crime scene will be underestimated where the suspect population includes one or more of the suspect's close relatives. *Id.* at 6. The problem is greatest in small, isolated populations with atypically constrained mating, *e.g.*, in the Pennsylvania Amish community, certain Native American tribes, etc. *Id.* at 2-3.

(continued...)

B. The Effect of Section 10-915 on Admission of Population Genetics Statistics

Although § 10-915 does not explicitly discuss the use of population genetics statistics, there are several indications in the statute that the Legislature also intended the supporting statistics to be routinely admitted along with the DNA match evidence. While the scientific dispute discussed above might at one point have required exclusion of population genetics under the *Frye-Reed* standard, the statute renders *Frye-Reed* analysis unnecessary.

First addressing the language of the statute, the General Assembly amended the DNA statute in 1991 to specifically include a provision referring to population genetics. 1991 Maryland Laws ch. 631, at 3447-49 (1991) (codified as amended at § 10-915); *see also* House Bill No. 1150. As amended, the statute now requires that the proponent of DNA evidence provide, upon the opponent's request, "a statement setting forth the allele frequency and genotype data for the appropriate data base utilized." § 10-915(b)(2)(v). *See also supra* note 10. This language clearly indicates that the Legislature was aware that population genetics were used in support

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[30](...continued)
This argument arose in *United States v. Two Bulls,* 918 F.2d 56 (8th Cir. 1990), *vacated and dismissed as moot*, 925 F.2d 1126 (8th Cir. 1991) (en banc). The defendant in *Two Bulls* was a Native American, and the relevant suspect population included a large number of people with the same tribal background as the defendant. *See* Lempert, *supra*, at 5, n.9.

of DNA evidence, and moreover, that the Legislature expected such information to be presented at trial and used in cross-examination. This amendment preceded Armstead's trial, and Armstead received all the discovery information required under the amended statute.

In addition, the preamble language discussed above referring to an "infinitesimal margin of error," also demonstrates that the Legislature knew that statistical calculations were routinely applied to gauge the accuracy of DNA profile evidence. *See supra* Section IV.B.1. Furthermore, the fact that the Legislature deleted the words "unique" and "uniquely" from House Bill 711 before enacting the DNA statute reflects an awareness that not all segments of DNA are unique and, therefore, that there is some possibility of random matching. Even before the statute was amended, therefore, the Legislature clearly recognized that the odds of random matching would be at issue whenever DNA evidence was presented.

Moreover, the statutory language stating that DNA profile evidence is admissible "to prove or disprove . . . identity," § 10-915(b), also indicates that the Legislature viewed population genetics statistics as a necessary component of DNA evidence. As stated in the NRC Report, "[t]o say that two patterns match, without providing any scientifically valid estimate (or, at least, an upper bound) of the frequency with which such matches might occur by chance, is meaningless." NRC REPORT, *supra*, at 3-1.

Courts in other jurisdictions have also recognized this problem, observing that: "Without the probability assessment, the jury does not know [whether the matching] patterns are as common as pictures with two eyes, or as unique as the Mona Lisa." *United States v. Yee*, 134 F.R.D. 161, 181 (N.D. Ohio 1991), *aff'd sub nom United States v. Bonds*, 12 F.3d 540 (6th Cir. 1993). *See also Nelson v. State,* 628 A.2d 69, 75 (Del. 1993)*; State v. Cauthron,* 120 Wash.2d 879, 846 P.2d 502, 516 (1993); *United States v. Porter,* 618 A.2d 629, 640 (D.C. 1992); *Com. v. Lanigan*, 413 Mass. 154, 596 N.E.2d 311, 314 (1992) (*Lanigan I*), *aff'd in part and rev'd in part*, 419 Mass. 15, 641 N.E.2d 1342 (1994) (*Lanigan II*); *State v. Vandebogart,* 136 N.H. 365, 616 A.2d 483, 494 (1992), *modified on reh'g,* 139 N.H. 145, 652 A.2d 671 (1994); *People v. Marlow*, 41 Cal. Rptr. 2d 5, 29 & n.42 (Ct. App. 1995), *cert. granted*, 1995 Cal. LEXIS 4583 (July 20, 1995) (No. G013492); *People v. Soto,* 35 Cal. Rptr. 2d 846, 855 (Ct. App. 1994), *cert. granted*, 890 P.2d 1115 (Cal. 1995); *State v. Watson,* 257 Ill. App. 3d 915, 629 N.E.2d 634, 644 (App. Ct. 1994), *cert. denied,* 642 N.E.2d 1299 (Ill. 1994).

If random DNA matching is possible, then a "match" between two DNA profiles is not meaningful without contextual statistics regarding the odds that the match was coincidental. *United States v. Yee,* 134 F.R.D. 161, 181 (N.D. Ohio 1991), *aff'd sub nom United States v. Bonds,* 12 F.3d 540 (6th Cir. 1993); *Lanigan*, 596 N.E.2d

at 314, *Cauthron,* 846 P.2d at 516. The General Assembly recognized the possibility of random matching, as indicated by the 1991 amendment and the preamble to the statute; therefore, in rendering DNA evidence admissible, we conclude that the Legislature intended to render the necessary contextual statistics admissible, not just the "raw" evidence of a DNA match. This interpretation is in accord with common sense because to interpret the statute otherwise would provide juries with DNA evidence that they could not evaluate in a logical manner.

We recognize that some courts have allowed use of DNA match evidence without supporting statistics.[31] *See, e.g., Com. v. Crews,* 640 A.2d 395 (Pa. 1994). We believe, however, that the better

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[31]Among the courts that have found statistical evidence inadmissible, there have been at least three different approaches to the use of DNA "match" testimony:

> (1) Disallow use of the DNA match as well, because it is meaningless without contextual statistics;
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> (2) "Uncouple" the match evidence from the statistical evidence, permitting testimony as to the match; or
>
> (3) Permit testimony regarding the match, and allow expert testimony regarding the frequency of occurrence of each allele in the general population, but disallow testimony giving an overall probability of match (thus, avoiding the product rule issue, because the probabilities are not combined).

See State v. Bible, 175 Ariz. 549, 858 P.2d 1152, 1190 (1993), *cert. denied*, U.S. , 114 S. Ct. 1578 (1994).

approach is to treat the match and the statistics as inseparable components of DNA evidence.[32] *Cf. Keirsey v. State,* 106 Md. App. 551, 575, 665 A.2d 700, 712 (1995).[33]

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[32]To the extent that *Jackson v. State*, 92 Md. App. 304, 608 A.2d 782 (1992), *cert. denied*, 328 Md. 238, 614 A.2d 84 (1992), is inconsistent with this holding, it is hereby disapproved. In *Jackson,* the defendant argued that expert testimony that his DNA matched DNA from the crime scene should not have been admitted because no population genetics statistics were provided to put the "match" testimony in context, asserting that "without proper evidence regarding the probability of a match, evidence that a match was declared has no relevance. Without probability calculations the fact that there was a match does not tend to make it more or less likely that [a]ppellant was the assailant." 92 Md. App. at 324, 608 A.2d at 791. While the court found that this argument had been waived, it noted that: "In any event, we have explained that DNA testing has been legislatively determined to be reliable and is generally admissible in Maryland. The expert witness testified that she used standard procedures and standard equipment in conducting the testing and comparisons. There was simply no need for the State to offer additional evidence, such as probability calculations, to establish that the testing procedures employed were reliable." *Id.* at 324, 608 A.2d at 792.

[33]In *Keirsey*, the Court of Special Appeals held that the *Frye-Reed* test was inapplicable to the methods of calculating population genetics statistics, stating that "the *Frye-Reed* test . . . is applicable only when an essential component of the expert's opinion is a scientific test result 'controlled by inexorable, physical laws.'" 106 Md. App. at 575, 665 A.2d at 712 (quoting *State v. Allewalt*, 308 Md. 89, 98, 517 A.2d 741, 745 (1986)). We believe this description of the scope of the *Frye-Reed* test is too limited, excluding some mathematical techniques that should be subjected to reliability analysis.

The *Frye-Reed* test often will not apply to statistical calculations because the choice between alternative statistical techniques, although subjective, is often merely a choice between equally valid methods of describing the same underlying scientific data. Statistics are inherently flexible, and thus there are usually multiple correct statistics that can be used to describe the same set of data. Statisticians routinely make

(continued...)

Thus, we conclude that § 10-915 encompasses both the evidence

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[33](...continued)
choices in presenting data; for example, they may choose to present either the mean, the median, or the mode to describe the "center" of a data set. This type of format choice is not subject to *Frye-Reed* analysis.

There are, however, instances, as in this case, where the proper choice of statistical techniques is dependent on an underlying scientific phenomenon or principle. For example, suppose that a new species of flower is discovered. When it is discovered, a white-flowered variety and a red-flowered variety are observed. It would be incorrect to calculate the probability of a new plant having white flowers based on a normal distribution, because this would depend on whether flower colors varied along a continuum from white to pink to red, or whether there were only discrete possibilities for the flower color, *i.e.*, white or red. *See* R. FREUND & W. WILSON, STATISTICAL METHODS 65-66, 70-76. Under this scenario, the correct choice of probability calculations would depend on the underlying genetics of the plant.

We believe the choice between population genetics approaches--*i.e.*, the product rule versus the ceiling principle--is similarly dependent on an underlying scientific hypothesis, because if the scientific data showed significant variation in allele frequencies across subpopulations, this would imply that use of the product rule was incorrect. Other courts have also adopted this view. For example, in *People v. Soto,* 35 Cal.Rptr. 2d 856 (Ct. App. 1994), *cert. granted,* 890 P.2d 1115 (Cal. 1995), a California court determined that the *Frye* standard applied to the population genetics formulae used to analyze DNA evidence. *Id.* at 858. Because the scientific data has shown the variation in allele frequencies to be insignificant, however, the *Soto* court ultimately concluded that both the product rule and the ceiling principle passed the "general acceptance" test. *Id. See also* E. IMMWINKELRIED, THE METHODS OF ATTACKING SCIENTIFIC EVIDENCE § 6.6(D), at 228-29 (1982).

Although we therefore disagree with the Court of Special Appeals' circumscribed view of the *Frye-Reed* test, we need not carry our analysis as far as in *Soto*, because the Maryland General Assembly has determined that statistical evidence of the odds of a random DNA match is admissible.

of a DNA match and the supporting statistics. Although § 10-915 does not specify which statistical methodology should be used, *i.e.*, the product rule or the ceiling principle, the Legislature need not reach this level of specificity in order for the statistical information to be admitted. For example, as originally enacted, the statute did not specify which type of DNA analysis was admissible; the Legislature only added the requirement that the evidence be collected using the RFLP method when the statute was amended in 1991. 1991 Maryland Laws ch. 631, at 3448 (codified as amended at § 10-915(b)). This lack of specificity can not be read to mean that DNA analysis was inadmissible until the Legislature committed to one specific method.

Moreover, if the Legislature specified the precise method to be used for each critical step in DNA analysis, it would stultify scientific development.[34] In *Haines v. Shanholtz*, 57 Md. App. 92, 468 A.2d 1365 (1984), *cert. denied,* 300 Md. 90, 475 A.2d 1201 (1984), the Court of Special Appeals discussed this point in describing why the Legislature chose not to codify the specific calculations to be used in determining the probability of paternity:

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[34]Taken to the extreme, this approach would require the Legislature to specify not only the type of statistical formula to be applied, but also the type of probe to be used, the number of loci to be tested, the minimum database size, and a multitude of other details which impact on the accuracy and reliability of the results.

> The legislation . . . carefully refrained from adopting any specific tests to establish the percentages necessary to include or exclude putative fathers. It is reasonable to assume that the General Assembly recognized that new technology may become available and, by not addressing any specific combination of tests, laboratories will be allowed to utilize the most effective tests without further legislative change.

Id. at 96, 468 A.2d at 1367. To codify every step in a technological process such as DNA profiling would be to freeze the process in time, precluding the introduction of better procedures and potentially more accurate evidence without a subsequent change in the law. *Cf. State v. Bible,* 175 Ariz. 549, 858 P.2d 1152, 1189 n.33 (1993), *cert. denied*, U.S. , 114 S. Ct. 1578 (1994).[35]

Petitioner is simply wrong when he argues that the Court is obliged to reconsider the reliability of the product rule in light of the NRC Report and other recent scientific developments. While due process considerations require courts to intervene if scientific opinion shifts so dramatically that previously accepted

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[35]While the court in *Bible* acknowledged the evolutionary nature of scientific development, observing that "neither logic nor authority supports confining ourselves to a snapshot, rather than viewing the motion picture, of technological advancement," it used this principle to support a different conclusion than the one we reach here. 858 P.2d at 1189 n.33. The *Bible* court concluded that on appeal, review of the trial court's *Frye-Reed* analysis should not be limited to the level of acceptance of DNA testing at the time of trial, but rather should also consider subsequent scientific developments. *Id.* The *Bible* court, however, was not determining the scope of admissibility under a statute, but rather considered the admissibility of DNA evidence in a jurisdiction without legislation governing admissibility.

methods are considered unreliable, § 10-915 shifts the responsibility to the Legislature to respond to incremental advances in technology that do not effect sufficient change to implicate due process. Although Petitioner argues, as discussed in Section VI, *infra*, that there has been a significant shift in scientific opinion, such that the product rule has become outmoded, we disagree. Neither the NRC report nor the ensuing scientific publications support such a conclusion. *See* NRC REPORT, *supra*, at S-11 to S-12; B. Budowle & E. Lander, *DNA Fingerprinting Dispute Laid to Rest*, 371 NATURE 735, 737-38 (1994). On the contrary, both methods have been proven viable in light of the most recent scientific evidence. *See* VNTR POPULATION DATA STUDY, *supra,* at 6; Budowle et al., *supra,* at 349. Section 10-915 does not specify a particular statistical method; therefore, it was appropriate for the trial court to permit the results of both calculations to be presented in court. *Cf. Soto,* 35 Cal. Rptr. 2d at 858-59 (affirming the trial court's decision to admit both the product rule and ceiling principle calculations under the *Kelly-Frye* standard).

We hold that the trial court did not abuse its discretion in admitting the statistical evidence regarding the probability of a random DNA match calculated using the product rule because the statute contemplates the use of probability evidence to place the "raw" result of a DNA match in context. Furthermore, the

Legislature need not specify the particular statistical method to be used. Because the statute does not specify a method, either the product rule or the ceiling principle may be applied and presented in evidence.

VI. Due Process Considerations

Petitioner next contends that the DNA evidence is so unreliable that its use violates his due process rights. He bases his contention that the DNA evidence was unreliable on both generalized problems with DNA testing and specific problems with the conduct of the testing in his case. His generalized attack focuses on the use of the product rule rather than the ceiling principle, which he contends renders the statistical component of the DNA evidence unreliable. He also argues that because the laboratory error rate, 0.7%, greatly exceeds the odds of random matching under either the product rule or the ceiling principle, both methods of calculating the odds are unreliable.

In addition, he attacks several specific defects in the conduct of the testing in his case. The first technical defect he discusses is the use of excessively large "match windows" in comparing his DNA with the DNA taken from the victim. Match windows must be used due to measurement error that is inherent in the DNA technique. Even if an identical piece of DNA was measured several times, the measurement would likely differ to a small

degree. Therefore, match windows are used to account for this margin of error.[36] If match windows are too large, two fragments may be declared a match when they actually differ. Petitioner argues that this problem rendered his test results unreliable. Petitioner also argues that error in the testing yielded bands in one test that did not appear in another test, a phenomenon the laboratories attributed to "star activity," or essentially excessive activity of the restriction enzymes used to cut the DNA. Third, he argues that the statistics on odds of a random match failed to account for the higher degree of genetic similarity between Petitioner and his siblings.

We begin our analysis with the proposition that "a part of the due process guarantee is that an individual not suffer punitive action as a result of an inaccurate scientific procedure." *Higgs v. Wilson,* 616 F. Supp. 226, 230 (W.D. Ky. 1985), *vacated and remanded on other grounds*, 793 F.2d 1291 (6th Cir. 1986), *aff'd in part, vacated in part, and remanded in part on other grounds sub nom Higgs v. Bland*, 888 F.2d 443 (6th Cir. 1991). Scientific test results, however, need not be infallible to meet the standard for due process. *Dowling v. United States*, 493 U.S. 342, 352-53, 110

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[36]The FBI will declare a match between two fragments of DNA if the size of one fragment is within 2.5% of the size of another. To illustrate, if fragment A is 10,000 nucleotides long, while fragment B is 10,250 nucleotides long, they will still be declared a "match." Cellmark uses a match window that varies with the size of the DNA fragment.

S. Ct. 668, 674, 107 L. Ed. 2d 708, 720 (1990). As the Supreme Court has stated, the due process standard only bars admission of evidence that is "so extremely unfair that its admission violates 'fundamental conceptions of justice.'" *Id.* at 353 (quoting *United States v. Lovasco*, 431 U.S. 783, 97 S. Ct. 2044, 52 L. Ed. 2d 752 (1977) (citations omitted)). The Supreme Court has construed this test narrowly, *id.* at 352, as have the Maryland courts. *Crawford v. State*, 285 Md. 431, 404 A.2d 244 (1979). For evidence to violate this standard because of its unreliability, the acts complained of must "be of such quality as necessarily prevent a fair trial." *Id.* at 452, 404 A.2d at 255 (quoting *Lisenba v. California*, 314 U.S. 219, 62 S. Ct. 280, 86 L. Ed. 166 (1941)).

"Fundamental fairness" is an inherently malleable concept and, thus, does not lend itself to formulation of a bright-line rule. The issue of "fundamental fairness" must instead be assessed on the facts of each case. While there is neither a blanket test for fundamental fairness nor well-defined factors to guide trial courts, the Supreme Court has provided some broad considerations to weigh in assessing "fundamental fairness." For example, in *Dowling v. United States*, 493 U.S. 342, 110 S. Ct. 668, 107 L. Ed. 2d 708 (1990), the Petitioner was tried for an armed bank robbery in which the perpetrator had been wearing a ski mask and carrying a small pistol. A witness, Veronica Henry, testified that two weeks after the incident, the Petitioner had attempted to rob her, while

wearing a ski mask and carrying a small pistol. *Id.* at 344-45. Although Dowling had been acquitted of the robbery of Henry, the Court held that Henry's testimony was not so "fundamentally unfair" that it violated Dowling's due process rights. *Id.* at 353. In rejecting Petitioner's due process challenge, the Court emphasized the jury's ability to weigh the evidence, and the Petitioner's opportunity to challenge the testimony. *Id.*

Maryland courts have also considered the question of when evidence should be deemed so unreliable that it violates due process. The Court of Special Appeals has considered the issue, for example, in the context of paternity testing in *Kammer v. Young,* 73 Md. App. 565, 576-77, 535 A.2d 936, 941-42 (1988), *cert. denied*, 488 U.S. 919 (1988). In *Kammer*, the court considered a due process challenge to the reliability of calculations of the probability of the defendant's paternity. By statute, paternity testing must exclude 97.3% of possible biological fathers to be admitted. Md. Code (1984, 1991 Repl. Vol., 1995 Cum. Supp.) § 5-1029(e)(1)(ii) of the Family Law Article. The defendant in *Kammer* argued that the conditional probability formula that was used to calculate the probability of his paternity was so unreliable that his due process rights were violated. *Id.* at 574, 535 A.2d at 940-41. The intermediate appellate court held, however, that his rights were not violated, explaining that:

> Appellant was free to, and in fact did, put on non-genetic evidence which not only disputed

> generally his paternity but, in effect, was an attack upon the use of the . . . [conditional] probability figure. This allowed him an opportunity to counterbalance appellee's introduction of the blood test results and the prior probability on which they were based and served to protect his due process rights.

Id. at 577, 535 A.2d at 942. *Cf. Wilson v. State*, 70 Md. App. 527, 534, 521 A.2d 1257, 1262 (1987).

This Court has not previously considered the due process implications of the reliability of *scientific* evidence. In other contexts, however, we have considered whether evidence was sufficiently reliable to satisfy due process. For example, in *Department v. Bo Peep,* 317 Md. 573, 565 A.2d 1015 (1989), *cert. denied,* 494 U.S. 1067 (1989), the Department of Human Resources held a hearing regarding revocation of Bo Peep Nursery's license based on allegations of child abuse. In the hearing, the agency's case against the nursery was based entirely on hearsay evidence. We held, however, that the exclusive use of hearsay, in the context of an administrative hearing, did not violate the nursery's due process rights. *Id.* at 598-602, 565 A.2d at 1027-29. In so holding, we pointed to Bo Peep's opportunity to cross-examine adult witnesses who spoke with the children. *Id.* at 601, 565 A.2d at 1028-29. We also contrasted this situation with cases where due process was violated because the defendant was completely unaware of the evidence his opponent intended to present, and thus had "no opportunity for cross-examination or rebuttal." *Id.* at 598-99, 565

A.2d at 1027 (quoting *Rogers v. Radio Shack,* 271 Md. 126, 129, 314 A.2d 113, 115 (1974)).

From these cases, we distill the principle that the essence of the due process "fundamental fairness" inquiry is whether there was a balanced, fully explored presentation of the evidence. This balance in turn depends on the jury's ability to weigh the evidence, and the defendant's opportunity to challenge the evidence. *See Dowling*, 493 U.S. at 353.

Applying these principles to the present case, we first consider the Petitioner's generalized challenges to the DNA evidence, *i.e.*, the use of the product rule and the magnitude of the laboratory error rate compared to the odds of random matching. As we noted above, the most recent scientific data confirms that both the product rule and ceiling principle methods are viable, and therefore both are sufficiently reliable to satisfy due process. *See supra* Section V; *see also* VNTR POPULATION DATA STUDY, *supra*; Budowle et al., *supra.* We therefore conclude that because the jury was presented with both the product rule and ceiling principle calculations, with full explanations of both methods, it had the opportunity to weigh the contested evidence. In addition, although the Petitioner did not call independent experts at trial, we conclude that he had ample opportunity to challenge the product rule calculations.

We next turn to Petitioner's argument that the magnitude of

the laboratory error as compared to the odds of random DNA matching renders the odds of random matching meaningless. Essentially, Petitioner argues that the DNA testing procedure is inaccurate due to lab error in 0.7% of cases.[37] This means that in seven cases out of one thousand, an erroneous match may be found. Given this, he argues, it is improper to say that there is only one chance in 800,000 that the DNA match was "random" because there is at least a 0.7% chance of erroneous matching due to laboratory error. As we indicated above, however, the jury was fully informed of the laboratory error rate and the Petitioner had a full opportunity to address this on cross-examination. Therefore, there was no due process violation.

Finally, considering the Petitioner's specific challenges to the DNA testing procedures used in his case, we first observe that although Petitioner characterizes his objection to the use of "match windows" as a case-specific challenge, it is really a general challenge to DNA testing. The use of match windows is an inherent component of the process of DNA testing. Regarding Petitioner's other case-specific challenges, we conclude that these issues were fully presented to the jury at trial, and the jury was able to factor them into its assessment of the DNA evidence. The

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[37]The laboratory error rate of 0.7% for Cellmark was based on two errors identified in proficiency tests conducted in 1988. Since that time, the laboratory protocol has been revised to address these problems.

alleged technical defects related to the DNA testing were fully explained to the jury by the experts. We can not say that the data was so unreliable on its face that petitioner's due process rights were violated. Under the circumstances presented herein, we find that these technical issues go to the weight of the DNA evidence, not its admissibility.

Petitioner had the opportunity to challenge the DNA evidence and to raise both components of potential error on cross-examination, and he did so. In discovery, the State provided all the background information the proponent of DNA evidence is required to provide under § 10-915 (b)(1) & (b)(2), facilitating thorough cross-examination. *Cf. Jackson v. State*, 92 Md. App. 304, 322-23, 608 A.2d 782, 791 (1992) (petitioner raised a due process objection at trial, but dropped his constitutional arguments on appeal), *cert. denied*, 328 Md. 238, 614 A.2d 84 (1992). Therefore, his due process rights were not violated by presenting this thoroughly explored evidence to the jury.

JUDGMENT OF THE COURT OF SPECIAL APPEALS AFFIRMED. COSTS TO BE PAID BY THE PETITIONER.

IN THE COURT OF APPEALS OF MARYLAND

NO. 133

SEPTEMBER TERM, 1993

MICHAEL DEVON ARMSTEAD

V.

STATE OF MARYLAND

Murphy, C. J.
Eldridge
Rodowsky
Chasanow
Karwacki
Bell
Raker

JJ.

DISSENTING OPINION BY BELL, J.

FILED: March 20, 1996

I agree with the majority that the petitioner is not entitled to a Frye-Reed hearing[1] or an "inverse Frye-Reed" hearing.

[1] Frye v. United States, 293 F.1013 (D.C.Cir. 1923) and Reed v. State, 283 Md. 374, 391 A.2d 364 (1978). Frye established the general acceptance test for the admissibility of new scientific evidence. Id. at 1014. This Court adopted the Frye Test in Reed. See 283 Md. at 389, 391 A.2d at 372. In Daubert v. Merrell Dow Pharmaceuticals Inc., 509 U.S. ___, ___, 113 S.Ct. 2786, 2793, 125 L.Ed.2d 469, 479 (1993), the Supreme Court addressed the viability of the Frye test as a rule of evidence, concluding that, in the federal courts, it was superseded by the adoption of the Federal Rules of Evidence, in particular Rule 702, which provides:

> 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.

The Court construed the rule as rendering all relevant expert evidence admissible if it will assist the trier of fact. Id. at ___, 113 S.Ct. at 2795, 125 L.Ed.2d at 480. The Court explained:

> Nothing in the text of Rule [702] establishes "general acceptance" as an absolute prerequisite to admissibility....[T]he court ordinarily should consider the known or potential rate of error..., and the existence and maintenance of standards controlling the technique's operation.

Id. at ___, 113 S.Ct. at 2794, 2797, 125 L.Ed.2d at 480, 483. (citations omitted).

The holding in Daubert indicates that there is an appreciable difference between general acceptance, as determined by the Frye-Reed standard, and admissibility under the Federal Rules of Evidence.

Assuming the latter to mean an attack on the general acceptance in the relevant scientific community of the scientific technique underlying DNA profiling,[2] Maryland Code (1974, 1989 Repl. Vol., 1992 Cum. Supp.) § 10-915 of the Courts and Judicial Proceedings Article,[3] was enacted precisely "to eliminate the necessity of

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[2] The petitioner concedes that the scientific principles underlying DNA profile analysis are generally reliable. He argues, however, that he should have been permitted to conduct what he terms an "inverse Frye-Reed" hearing to address new developments in, and new assessments of, the statistical probability methodology in use when Maryland Code (1974, 1989 Repl. Vol. 1992 Cum. Supp.) § 10-915 of the Courts and Judicial Proceedings Article was enacted. Developments in the laboratory testing procedures, he avers, indicate that the probabilities obtained by the product rule method are not reliable and, indeed, that the methodology itself is no longer generally accepted in the relevant scientific community, if it ever was. This, he concludes, renders the results in this case unreliable.

[3] Maryland Code (1984, 1995 Repl. Vol.) § 10-915 of the Courts and Judicial Proceedings Article provides, in its entirety:

> (a) Definitions--
> (1) In this section the following words have the meanings indicated.
> (2) "Deoxyribonucleic acid (DNA)" means the molecules in an all cellular forms that contain genetic information in a patterned chemical structure of each individual.
> (3) "DNA profile" means an analysis that utilizes the restriction fragment length polymorphism analysis of DNA resulting in the identification of an individual's patterned chemical structure of genetic information.
> (b) Purposes.-- In any criminal proceeding, the evidence of DNA profile is admissible to prove or disprove the identity of any person, if the party seeking to introduce the evidence of DNA profile:
> (1) Notifies in writing the other party or parties by mail at least 45 days before any criminal proceeding; and
> (2) Provides, if requested in writing, the other party or parties at least 30 days before any criminal proceeding with:

holding a preliminary Frye-Reed hearing to prove that the [DNA profiling] technique has gained general acceptance in the relevant scientific community." Floor Report of the Senate Judicial Proceedings Committee on HB 711, at 2 (1989). It is clear, therefore, that § 10-915 makes DNA profile analysis evidence admissible, generally.

I do not, however, accept the majority's conclusion, see Armstead v. State, ___ Md. ___, ___, ___ A.2d ___, ___ (1996) [slip op. at 25], that it also divests the trial judge of all discretion, except on the grounds of relevance and for "error," to consider, and decide whether proffered DNA profile evidence is admissible in a particular case. I believe that the petitioner is entitled to an evidentiary determination of the accuracy and, hence, reliability, of the laboratory procedures employed to profile him by DNA and of the results obtained, and to their exclusion, § 10-915 notwithstanding, if either is found lacking. See People v. Castro, 545 N.Y.S.2d 985, 999 (Sup. 1989) ("DNA forensic identification techniques and experiments are generally accepted in the scientific community and can produce reliable results. Hence, the Frye

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(i) Duplicates of the actual autoradiographs generated;
(ii) The laboratory protocols and procedures;
(iii) The identification of each probe utilized;
(iv) A statement describing the methodology of measuring a fragment size and match criteria; and
(v) A statement setting forth the allele frequency and genotype data for the appropriate data base utilized.

standard of admissibility is satisfied. [Even so, a] pre-trial hearing should be conducted to determine if the testing laboratory substantially performed the scientifically accepted tests and techniques, yielding sufficiently reliable results to be admissible as a question of fact for the jury."). Moreover, I am satisfied, as the petitioner contends, that § 10-915 does not divest trial courts of their discretion, under Maryland Rule 5-403, to exclude DNA profile evidence if its probative value is outweighed by its prejudicial impact.

I.

A.

The Frye-Reed hearing's purpose is to address, as a preliminary matter, the reliability of new scientific techniques. Reed, 283 Md. at 388, 391 A.2d at 371. It was never designed to determine whether proper testing procedures were employed in a particular case, or whether the results obtained were reliable. Those issues were left to the trial judge's determination, to be made in light of the evidence, including expert testimony, adduced at trial. Id. at 389, 391 A.2d at 372 ("Testimony based on a technique which is found to have gained `general acceptance in the scientific community' *may* be admitted into evidence, but only if a trial judge also determines, in the exercise of his discretion, as he must in all other instances of expert testimony, that the proposed testimony will be helpful to the jury, that the expert is

properly qualified, etc....").

Thus, even following a Frye-Reed hearing, in which the general acceptance of a scientific technique has been determined, the trial court still must monitor and pass upon the admissibility of the evidence offered with respect to that new technique. An evidentiary determination still must be made with regard to the relevance of the testimony, the qualifications of any expert witnesses, the adequacy of the foundation laid and whether the results were obtained from accurate and reliable procedures and protocol. Section 10-915 does nothing more than to "eliminate the need to conduct the Frye-Reed hearing," relating to the general acceptance of the technique; it does not obviate the need for the trial court to review the protocol and laboratory procedures associated with the new technique and determine whether the results were compiled from the actual procedures performed. The trial court must be satisfied that the generally accepted principles underlying the technique were accurately and appropriately applied and, thus, be convinced of the reliability of the results in that case. In other words, the trial court still must exercise discretion to determine the admissibility, in the specific case, of the DNA profile analysis results. State v. Houser, 490 N.W.2d 168, 181 (Neb. 1992) ("[T]he trial court, in determining admissibility of DNA evidence, must first be satisfied, and find, as to the general acceptance of relevant DNA theories in the scientific community and must be satisfied as to the acceptance and validity

of the methodology of testing DNA used. The trial court then determines if specific procedures were properly followed in the case before the court."). See also United States v. Two Bulls, 918 F.2d 56, 61 (8th Cir. 1990); Ex Parte Perry, 586 So.2d 242, 250 (Ala. 1991).

The majority concedes that § 10-915 "does ... permit case specific challenges to the manner in which a particular test was conducted." See Armstead, ___ Md. at ___, ___ A.2d at ___ [slip op. at 31]. It holds, however, that ordinarily the finding of an error or deviation from established protocol will affect the weight, not the admissibility of the evidence. Id. This holding flies in the face of the Daubert ruling in which the Supreme Court opined, "[U]nder the [Federal] Rules [of Evidence], the trial judge *must* ensure that any and all scientific testimony or evidence admitted is not only relevant, but reliable." Id. 509 S.Ct. at ___, 113 S.Ct. at 2795, 125 L.Ed.2d at 480 (emphasis added).

The majority speaks of a distinction between "mere measurement errors" and errors resulting from "deviations from accepted testing procedures." Armstead, ___ Md. at ___, ___ A.2d at ___ [slip op. at 28 n.18]. Both types of error are procedural in nature and affect the relevancy and the reliability of the results obtained. Therefore, as the COMMITTEE ON DNA TECHNOLOGY IN FORENSIC SCIENCE, NATIONAL RESEARCH COUNCIL REPORT (1992) [hereinafter NRC Report] notes, and the majority concedes, Id. at ___, ___ A.2d at ___ [slip op. at 28

n.18],

> The validity of [the] assumption ... that the analytical work done for a particular trial comports with proper procedures can be resolved only case by case and is always open to question even if the scientific reliability of DNA typing is fully accepted.... The DNA evidence should not be admissible if the proper procedures were not followed. Moreover, even if a court finds DNA evidence admissible because proper procedures were followed, the probative force of this evidence will depend on the quality of the laboratory work.

NRC Report at 6-4. See also Houser, 490 N.W.2d at 181 (citing Two Bulls, 918 F.2d 56; Prater v. State, 820 S.W.2d 429 (Ark. 1991); Perry, 586 So.2d 242; Smith v. Deppish, 807 P.2d 144 (1991)). I do not assume, as the majority apparently does, see Armstead, ___ Md. at ___, ___ A.2d at ___ [slip op. at 28 n.18], that the defects the petitioner alleges in this case constitute "mere measurement errors" or relate to the general reliability of DNA profiling as a scientific technique, rather than to the quality of the laboratory work and the accuracy of the procedures followed. In any event, one of the purposes of an evidentiary hearing to determine admissibility is to explore that issue.

The petitioner cites two defects in the testing procedures employed in his case, which, he avers, indicate that the laboratory testing did not follow the required procedures. He also argues that these defects render the DNA profile evidence so unreliable that its admission violates his right not to "suffer punitive action as a result of an inaccurate scientific procedure." Higgs

v. Wilson, 616 F.Supp. 226, 230 (D.C. Ky 1985) (citing United States v. Brown, 557 F.2d 541 (6th Cir. 1977)). First, the petitioner points to the fact that the match windows used to compare his DNA sample with the DNA sample obtained from the crime scene were excessively large. Although the use of match windows is inherent to DNA profiling, the Petitioner's challenge relates to the size, and not the use, of the match windows. The fact that they are excessively large, he asserts, as the majority also acknowledges, see Armstead, ___ Md. at ___, ___ A.2d at ___ [slip op. at 53], may result in two fragments being declared a match "when they actually differ."

The differences between the FBI autoradiographs and Cellmark's autoradiographs was offered, by petitioner, as another indication that the DNA evidence was inadmissible. The FBI autoradiographs showed a double band at one locus, while Cellmark's showed only one band at the same locus. A single band indicates that the DNA belongs to a homozygous[4] person, whereas a double band indicates that the person is heterozygous.[5] Absent a rare genetic mutation, the same person cannot be both homozygous and heterozygous for a given gene. Id. There was no testimony at the hearing, nor at trial, indicating that the petitioner possessed such a rare genetic

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[4] Homozygous means a person has two copies of the *same* allele for a particular gene. G. BEADLE & M. BEADLE, THE LANGUAGE OF LIFE 54-66 (1966).

[5] Heterozygous means a person has two *different* alleles or forms of a particular gene. Id.

mutation. The presence of shadow bands may be the result of laboratory error and, indeed, may indicate that the two samples do not match. NRC REPORT at 2-9 to 2-10.

The petitioner sought the opportunity to establish the former defect. As to the latter, the petitioner contends that the inconsistent results by the FBI and Cellmark indicate that both are so unreliable as to lack probative force and, hence, are inadmissible.

The majority dismisses the petitioner's second point as unpreserved, see Md. Rule 8-131(a), reasoning: "although petitioner raised the issue of shadow banding before the trial court as part of his due process challenge...he did not argue that the trial court retained its discretion under the statute to exclude the DNA evidence due to the shadow banding," Armstead, ___ Md. at ___, ___ A.2d at ___ [slip op at 30-31], and characterized the petitioner's argument regarding the inconsistency between the FBI and Cellmark results, as a general attack on the reliability of DNA profile analysis evidence, thus justifying its ultimate conclusion that § 10-915 does not allow it. Id. at ___, ___ A.2d at ___ [slip op. at 28 n.19].

The majority addressed the match window challenge on the merits. It rejected it as not offensive to due process. The majority also determined that, if there were defects in the application of the DNA profiling technique, that would affect only the weight, not the admissibility of the evidence. Id. at ___, ___

A.2d at ___ [slip op. at 28].

The petitioner's "shadow banding" argument is fully preserved for appellate review. It was the petitioner's position in the court below that he was entitled to a hearing at which he could explore the specific reliability and, hence, admissibility, of the DNA profiling tests performed by the State's expert witnesses. To be sure, the petitioner characterized his entitlement to such a hearing as a matter of due process, but, as I read the record, he did not rely on that vehicle exclusively. Indeed, the petitioner emphasized his due process rights only after the trial court indicated that it believed that § 10-915 precluded an evidentiary challenge, except as a matter of due process. Thus, not only was the petitioner entitled to have his "shadow banding" argument reviewed on the merits, but he was also entitled to a similar review, with respect to any other matter which the majority addressed only as a matter of due process.

The majority provides no justification for declaring that the petitioner's challenge to the reliability of the DNA profile testing done by the FBI and Cellmark is a general challenge to the reliability of DNA profile analysis evidence instead of a specific challenge to the accuracy of laboratory techniques used. In my opinion, it is the latter. So, too, are the petitioner's other challenges.

All of the petitioner's challenges relate to the specific laboratory procedures that were used in conducting the DNA profile

analysis. The petitioner does not complain that the principles underlying DNA profile analysis, as a scientific method, have not gained general acceptance in the relevant scientific community, rather, he argues that the testing procedures the FBI and Cellmark followed to "match" his DNA with the evidentiary DNA sample, were inaccurately performed and, so, produced unreliable results, and that the results reached by each laboratory were so inconsistent as to render both of them unreliable.

Nor do I agree with the majority's contention that individualized errors in the application of the DNA profile analysis technique should be treated "as matters of weight" and not as bearing on the admissibility of the proffered evidence. Adoption of this position inappropriately places on the jury, rather than the court, the responsibility of determining the reliability of the testing procedures and the results. See Satcher v. Commonwealth, 421 S.E.2d 821, 835 (Va. 1992).

In Satcher the Virginia Supreme Court considered a statute almost identical to § 10-915. It held that the trial court properly exercised discretion when it conducted an in camera hearing to determine the reliability of the DNA profile evidence offered in that case and thus balanced its probative value and prejudicial effect. Id. at 835. Characterizing the statute as "a rule of evidence, and [noting that] judges are well versed in administering rules of evidence without explicit guidance from the legislature," id., the court opined:

> [W]ide discretion must be vested in the trial court to determine, when unfamiliar scientific evidence is offered, whether the evidence is so inherently unreliable that a lay jury must be shielded from it, or whether it is of such character that the jury may safely be left to determine the credibility for itself.

Id. Thus, the petitioner is correct, when he argues that in determining whether to admit the results of DNA profiling techniques, the trial court should have considered, and decided, whether the laboratory procedures were conducted properly and whether there were testing errors affecting the relevance and reliability of the results produced.

B.

The majority recognizes that the petitioner is entitled to due process. It characterizes the due process to which he is entitled as merely a "balanced, fully explored presentation of the evidence...,[which] in turn depends on the jury's ability to weigh the evidence and the defendant's opportunity to challenge the evidence." Armstead, ___ Md. at ___, ___ A.2d at ___ [slip op. at 57]. It is enough, the majority posits, that the petitioner has the right to raise, and present to the jury at trial, his concerns about defects in the laboratory testing procedures utilized. That will enable the jury to determine, as it must, the weight to be given to those defects, it concludes. Id.

The right to call and cross examine witnesses is not, as the majority would have it, an exhaustive list of procedural due process entitlements. Phillips v. Venker, 316 Md. 212, 218, 557

A.2d 1338, 1341 (1989)("``due process' unlike some legal rules, is not a technical conception with fixed content unrelated to time, place, and circumstances'... (citation omitted), [r]ather it is `flexible and calls for such procedural protections as the particular situation demands.'")(quoting Morrisey v. Brewer, 408 U.S. 471, 481, 92 S.Ct. 2593, 2600, 33 L.Ed.2d 484 (1972))). In addition to calling and cross-examining witnesses, other procedural safeguards may include the right to a pre-trial hearing and the right to judicial review. Goldberg v. Kelly, 397 U.S. 254, 261 90 S.Ct. 1011, 1017, 25 L.Ed.2d 287, 295 (1970)("`Under all the circumstances, we hold that due process requires an adequate hearing...and the fact that there is a later constitutionally fair proceeding does not alter the result.'") (quoting Kelly v. Wyman, 294 F.Supp. 893, 901 (1968))). Boddie v. Connecticut, 401 U.S. 371, 378, 91 S.Ct. 780, 786, 25 L.Ed.2d 113, 119 (1971)("The formality and procedural requisites for the hearing can vary, depending upon the importance of the interests involved....").[6]

In the case sub judice, in my opinion, the petitioner was

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[6] Procedural due process in the administrative context may be satisfied by affording less than would be required in a criminal context, see Maryland State Police v. Zeigler, 330 Md. 540, 557-58, 625 A.2d 914, 922 (1993), and "administrative agencies are not generally bound by the technical common-law rules of evidence...." Montgomery County v. National Capital Realty Corp., 267 Md. 364, 297 A.2d 675, 681 (1972). Md Dep't of Human Resources v. Bo Peep Day Nursery, 317 Md. 573, 565 A.2d 1015 (1989), an administrative law case, upon which the majority heavily relies to determine the due process implications of the reliability of scientific evidence, Armstead, ___ Md. at ___, ___ A.2d at ___, [slip op. at 56], is not analogous.

entitled not only to cross examine the State's witnesses, to produce his own witnesses, i.e. to present a balanced version of the facts from his perspective, but he also had the right to a pre-trial evidentiary hearing to determine the admissibility of the State's proffered evidence.

The rules of procedure govern the admissibility of evidence and provide protection against due process infringements. See Venker, 316 Md. at 222, 557 A.2d at 1343 (1989); State v. Rusk, 289 Md. 230, 240, 424 A.2d 720, 725 (1981); Tichnell v. State, 290 Md. 43, 57, 427 A.2d 991, 998 (1981)(referencing "the protective purposes of the rules of evidence in criminal trials."). One such rule is Rule 5-702, which provides:

> Expert testimony may be admitted, in the form of an opinion or otherwise, if the court determines that the testimony will assist the trier of fact to understand the evidence or to determine a fact in issue. In making that determination, the court shall determine (1) whether the witness is qualified as an expert by knowledge, skill, experience, training or education, *(2) the appropriateness of the expert testimony on the particular subject, and (3) whether a sufficient factual basis exists to support the expert testimony.*

(Emphasis added).

Section 10-915, speaks to a threshold or preliminary matter, the acceptance in the relevant scientific community of DNA profile analysis evidence. Having determined that matter in favor of the proponent of the evidence, such evidence generally is admissible. DNA profile evidence is not exempt from other admissibility

prerequisites, prescribed by applicable rules of evidence, however, including relevance and such other considerations as may be prompted by specific challenges to its admissibility and reliability in the case in which it is offered. Reed, 283 Md. at 389, 391 A.2d at 372; Daubert, 509 U.S. at ___, 113 S.Ct. at 2798, 125 L.Ed.2d at 484.

Underlying Rule 5-702 is the premise that evidence that will be of assistance to the fact finder is relevant and, thus, is admissible. Simmons v. State, 313 Md. 33, 43, 542 A.2d 1258, 1263 (1988)("The critical determination is whether the jury will be aided by the opinion." (citation omitted)); State v. Allewalt, 308 Md. 89, 101, 517 A.2d 741, 747 (1986) (citing Consolidated Mechanical Contractors Inc. v. Ball, 263 Md. 328, 338, 283 A.2d 154, 159 (1971); Reed, 283 Md. at 389, 391 A.2d at 372.). In this case, the general acceptance of the DNA profile analysis technique notwithstanding, DNA profile analysis evidence is admissible only if it was obtained from accurately followed laboratory testing procedures. This is true because, if the proper procedures were not followed, the relevance of that evidence cannot be assured. And that lack of foundation, i.e. relevance, affects the admissibility of the evidence, since no sufficient factual basis will have been shown to support the expert opinion, as Rule 5-702 requires.

Whether accurate procedures were followed in conducting DNA profile analysis is critical to the factual basis for the expert's

opinion. Indeed, if the tests, on which the expert relies, were not accurately performed, it may not be assumed that the results obtained were accurate. Unless the facts, upon which the expert renders an opinion, i.e., the comparison of the defendant's DNA to the evidentiary DNA, are reliable, the expert's opinion simply cannot be admitted.

Rule 5-702 addresses an issue different from that considered by this Court in Reed. It is not directly concerned with the theory underlying a particular scientific technique or procedure, it relates only to the reliability and probativeness of specific evidence offered in a particular case. The Committee note to Rule 5-702 makes this clear: it states that the rule is not intended to overrule Frye-Reed principles; rather, the required scientific foundation for the admission of novel scientific techniques or principles is left to development by case law. Rule 5-702 is, thus, in a real sense, a codification of the precautionary recognition in Reed, that testimony based on a scientific technique is admissible only when found to be generally accepted in the relevant scientific community *and* the court has determined it to be otherwise admissible. Reed, 283 Md. at 389, 391 A.2d at 372.

The majority makes no mention of Rule 5-702 in its analysis. Instead, it interprets § 10-915 as broadly prohibiting a trial judge's exercise of discretion to exclude DNA evidence, even when individualized errors have been committed in the course of

gathering and compiling that evidence. Thus, the majority, presumes that "§ 10-915 has eliminated some of the trial court's gatekeeping responsibilities with regard to DNA evidence...." Armstead, ___ Md. at ___, ___ A.2d ___ [slip op at 25].

Because Rule 5-702 permits a trial court to exclude expert testimony for which it has determined no adequate foundation has been provided, it most assuredly imposes on the court a gatekeeping responsibility. I read the majority opinion as stripping the trial court of that responsibility when the proffered evidence offered is DNA evidence. To the extent that this is the majority's intention, it renders per-se admissible virtually any evidence an expert may proffer as DNA profile analysis. By so doing, the majority fails to recognize the difference between the preliminary determination of the general acceptance of DNA profile analysis evidence to prove identity, which is § 10-915's sole function, and its admissibility in a specific case.

To illustrate the important distinction between the threshold issue - general acceptance in the scientific community of proffered evidence - and the narrower, more specific issue of the admissibility, as reliable, of particular evidence in a particular case, it is only necessary to consider what happens when a particular exception to the hearsay rule, e.g., excited utterances, see, Rule 5-803(b)(2), is raised as the basis for the admission of a proffered statement. Clearly, a statement offered as an excited utterance is admissible, but only if its proponent is able to lay

the proper foundation, i.e., prove that it is what it is characterized as being. See Md. Rule 5-803(b)(2). So, too, in this case. The State proffered DNA profile analysis evidence, which, it says, tends to prove the identity of the perpetrator of the crime on trial. Section 10-915 requires the admission of that evidence, except when the court determines that it is irrelevant to the issues in the case, as the majority specifically recognizes, or finds that accurate testing procedures were not followed, see NRC Report at 6-4; or pursuant to Rule 5-702, the court concludes that the necessary factual predicate for the expert's opinion has not been shown.

This Court in Reed, supra, recognized the distinction between the threshold issue of the reliability of a scientific technique and the determination a trial judge is required to make pursuant to Rule 5-702 - whether particular facts will assist the jury in resolving a particular case:

> The question of the reliability of a scientific technique or process is unlike the question, for example, of the helpfulness of particular expert testimony to the trier of facts in a specific case. The answer to the question about the reliability of a scientific technique or process does not vary according to the circumstances of each case. *It is therefore inappropriate to view this threshold question of reliability as a matter within each trial judge's individual discretion*.

Reed, 283 Md. at 381, 391 A.2d at 367 (emphasis added). The use of the phrase "threshold question of reliability" indicates that this

determination is preliminary in nature and is not dispositive with respect to whether particular evidence is admissible. The reliability of the specific laboratory procedures used and the results obtained, albeit bearing on and related to the threshold issue, is, as we have seen, firmly committed to the sound discretion of the trial court.

To be sure, the legislature can, as it has done, via § 10-915, pre-determine that a scientific technique is generally accepted in the relevant scientific community, thus, avoiding the need for judicial decision on a case-by-case basis. It cannot pre-determine, however, that the tests performed pursuant to that technique, or the results obtained, are reliable and, thus, admissible in a particular case. As we observed in Reed, such a determination will depend on a case by case assessment. Id. See also Jackson v. State, 92 Md.App. 304, 323, 608 A.2d 782, 791 (1992); Polk v. State, 48 Md.App. 382, 391-92, 427 A.2d 1041, 1047 (1981). DNA profile analysis evidence simply is not per se admissible; its admissibility, in a particular case to prove identity, is case and fact specific. Proof that the DNA analysis offered in a particular trial is reliable is a prerequisite to its admissibility.

C.

The Petitioner, relying on Rule 5-403, also contends that, as a matter of statutory construction, § 10-915 notwithstanding, the trial court was required to balance the probative value of the

evidence against its prejudicial effect before admitting the DNA profile.

Unlike Rule 5-702, which pertains only to expert evidence, Rule 5-403 has a broader reach. It provides:

> 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.

It is applicable to all evidence determined to be relevant. By its terms, the court is required to balance the probative value of such evidence against its prejudicial effect. In other words, the admissibility of even relevant evidence depends upon that evidence being more probative than prejudicial. Holman v. Kelly Catering Inc., 334 Md. 480, 495, 639 A.2d 701, 708 (1994) citing, Hunt v. State, 312 Md. 494, 504, 540 A.2d 1125, 1130 (1988); Daubert, 509 U.S. at ___, 113 S.Ct. at 2797-98, 125 L.Ed.2d at 484 ("[A] judge assessing a proffer of expert scientific testimony under Rule 702 should also be mindful of other applicable rules.... Rule 403 permits the exclusion of relevant evidence `if its probative value is substantially outweighed by the danger of unfair prejudice, confusion of the issues, or misleading the jury....'"). Unless § 10-915 provides otherwise, DNA profile evidence must meet this test.

The majority asserts, "By enacting Section 10-915 and thereby

eliminating the need for the Frye-Reed hearings, the General Assembly legislatively determined that the probative value of DNA outweighs any prejudicial effect." Armstead, ___ Md. at ___, ___ A.2d at ___ [slip op. at 24]. It concludes that § 10-915 has "eliminated the discretion of the trial court to weigh probative value against prejudicial impact." Id. at ___, ___ A.2d at ___ [slip op. at 25]. There is nothing, however, in § 10-915 or in its legislative history to support this assertion.

The probative value/prejudicial effect balance is dependent upon the particular facts and circumstances of a given case. See Jackson v. State, 340 Md. 705, 717, 668 A.2d 8, 14 (1995). It cannot be pre-determined or pre-ordained even by Legislative enactment, without infringing due process. This is so because determining the probative value of DNA profile evidence entails a fact specific review of the accuracy of the laboratory testing procedures used and the reliability of the results produced. The shadow banding, the size of the match windows, and the different statistical conclusions drawn by the FBI, as compared to those reached by Cellmark, despite the fact that they were purportedly using the same methodologies, bear on the probative value of the proffered evidence. All implicate and are relevant to whether the testing procedures were accurately and reliably performed, which, in turn, bears on the accuracy and reliability of the results produced. Another relevant factor in the evaluation of the probative value and prejudicial impact of the proffered DNA

evidence is Cellmark's laboratory error rate.

That there is an inherent prejudice in the use of scientific evidence must also be considered. Given its esoteric and usually complex nature, there always is the danger that an expert presenting scientific proof will "assume a posture of mystic infallibility in the eyes of a jury." Reed, 283 Md. at 386, 391 A.2d at 370 (quoting United States v. Addison, 498 F.2d 741, 744 (D.C. Cir. 1974)). This danger is increased when the "proof" consists of statistical analysis, "based on the scientific principle that every human being has unique characteristics... having an aura of infallibility," Commonwealth v. Curnin, 565 N.E.2d 440, 441 (Mass. 1991), which produces a result expressed in terms of infinitesimal probabilities. Id. See also Houser, 490 N.W. 2d at 183-84. The complexity of DNA evidence, the unfamiliarity that most lay jurors have with respect to the subject and the likelihood that it will be perceived by such jurors as conclusive on the ultimate issue of identity has caused one court to observe:

> We cannot reasonably ask the average juror to decide such arcane questions as whether genetic substructuring and linkage disequilibrium preclude use of the Hardy-Weinberg equation and the product rule, when we ourselves have struggled to grasp these concepts. The result would be unpredictable. The juror would simply skip to the bottom line - the only aspect of the process that is readily understood - and look at the ultimate expression of match probability, without competently accessing the reliability of the process by which the laboratory got to the

bottom line.

People v. Barney, 10 Cal.Rptr.2d 731, 742 (Cal.App. 1992). Other courts have expressed the fear "that the testimony unduly encourages the trier of fact, in its determination of whether the State has proved guilt beyond a reasonable doubt, to focus solely upon a numerical conclusion and to disregard the weight of other evidence," Perry, 586 So.2d at 254, thus, equating the probability of a random match, which is the focus of DNA profile analysis, with the probability of guilt. State v. Boyd, 331 N.W.2d 480, 483 (Minn. 1983). The court, in Boyd, considering the admissibility of a statistical probability calculation, for the purposes of demonstrating the likelihood of a random match in the paternity context, cautioned,

> Testimony expressing opinions or conclusions in terms of statistical probabilities can make the uncertain seem all but proven, and suggest, by qualification, satisfaction of the requirement that guilt be established "beyond a reasonable doubt."

(quoting State v. Carlson, 267 N.W.2d 170, 176 (Minn. 1978)). See also Lewontin & Hartl, Population Genetics in Forensic DNA Typing, 254 Science 1745, 1749 (1991), in which the following observations were made:

> None of the statistical methods] take into account the probability of a false match through laboratory artifact or error. The rate of false positives defines a practical lower bound on the probability of a match, and probability estimates based on population data that are smaller than the false-positive rate

> should be disregarded. *Hence, probability estimates like 1 in 738, 000,000,000,000, however they are calculated, are terribly misleading because the rate of laboratory error is not taken into account.*

Id. (Emphasis added).

Another issue affecting the potential prejudice of DNA profile analysis evidence involves the debate which began in 1992, when the NRC Report proposed the use of the ceiling principle in lieu of the product rule. See NRC Report at S-11- S-14. See also, Lander, E.S. & Budowle, B.,"DNA Fingerprinting Dispute Laid to Rest," 371 Nature 735 (1994), in which two debatants, one a proponent of the ceiling principle and the other a proponent of the product rule, while conceding that their conclusion represented merely their "unanimous opinion", declared that the DNA fingerprinting controversy was over. But see Allan Sincox, Marijane Hemza - Placek, "Challenging the Admissibility of DNA Testing," 83 Illinois Bar Journal, 170 April 1995, indicating that the Lander- Budowle reconciliation has by no means eliminated or resolved the issue.[7] Thus, controversy

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[7] "In a recent article from Nature magazine, Bruce Budowle of the FBI and Eric Lander of MIT declared that there was no longer any controversy over population genetics issues. In response, 26 geneticists and statisticians sent a letter to Nature disagreeing with Lander and Budowle. Nature refused to publish it, in part because of the large number of authors." "Challenging the Admissibility of DNA Testing", 83 Illinois Bar Journal at 176 n.29. The portion of the letter most relevant to our discussion reads,

> Two of the most significant areas of controversy are the effect of population structure on match probabilities (including the broad question of applying appropriate population genetic and statistical principles to forensic

remains as to whether the results obtained by use of the product rule are generally accepted, see State v. Bible, 858 P.2d at 1152, 1188-89 (Ariz. 1993); State v. Cauthron, 846 P.2d 502, 514 (Wash. 1993); Barney, 10 Cal. Rptr.2d at 744; United States v. Porter, 618 A.2d 629, 640 (D.C.App. 1992); Commonwealth v. Lanigan, 596 N.E.2d 311, 315-16 (Mass. 1992); State v. Vandebogart, 616 A.2d 483, 494 (N.H. 1992), or reliable.[8]

> DNA analysis), and the essential role of laboratory error in the proper presentation of evidence. These issues are not, as Lander and Budowle assert, "purely academic." Rather, we who have expertise in population genetics and statistics, believe that these issues affect the very validity and reliability of the methods assessed from the witness stand....We would all like to end the DNA "wars", but this will not come about by two soldiers declaring an armistice while the bullets continue to fly. The new NRC committee, created largely at the request of the FBI, has an opportunity to clarify or reaffirm the many important recommendations of the first NRC committee. This committee can also address--one hopes with more specificity--those areas of DNA typing that remain controversial.

[8] In 1992, one year after House Bill 1150 was adopted by the General Assembly, the National Research Council Report, which the majority cites extensively throughout its opinion, made the following observations regarding statistical probability analysis, in general and the product rule method, in particular:

> What is the probability that such a match would have occurred between the suspect and a person drawn at random from the same population as the suspect? Answering that question requires calculation of the frequency in the population of each of the gene variants (alleles) that have been found, and the calculation requires a data bank where one can find the frequency of each allele in the population. On the basis of some *assumptions*, so-called Hardy-Weinberg rations can be calculated....Interpreting a DNA typing

analysis requires a valid scientific method for estimating the probability that a random person by chance matches the forensic sample at the sites of DNA variation examined....A standard way to estimate frequency is to count occurrences in a random sample of the appropriate population and then use classical statistical formulas to place upper and lower confidence limits on the estimate....Such estimates produced by straightforward counting have the virtue that they do not depend on theoretical assumptions, but simply on the samples having been randomly drawn from the appropriate population....In contrast, population frequencies often quoted for DNA typing analyses are based not on actual counting, but on theoretical models based on the principles of population genetics. Each matching allele is assumed to provide statistically independent evidence, and the frequencies of the individual alleles are multiplied together to calculate a frequency of the complete DNA pattern. Although a databank might contain only 500 people, multiplying the frequencies of enough separate events might result in an estimated frequency of their all occurring in a given person of 1 in a billion. Of course, the scientific validity of the multiplication rule [product rule] depends on whether the events (i.e., the matches at each allele) are actually statistically independent....*[T]here is not a sufficient body of empirical data on which to base a claim that such frequency calculations are reliable or valid*....The multiplication rule has been routinely applied to blood-group frequencies in the forensic setting. However, that situation is substantially different...and does not appear to lead to the risk of extrapolating beyond the available data for conventional markers. But highly polymorphic DNA markers exceed the informative power of protein markers and so multiplication of their estimated frequencies leads to estimates that are far less than the reciprocal of the size of the databanks, i.e.,

II.

The petitioner argues, I think correctly, that statistical probability evidence is not rendered admissible by § 10-915, which only addresses the admissibility of the "raw" evidence of a DNA match. Accordingly, since the trial court should have, but did not, conduct an evidentiary hearing to determine the reliability and admissibility of the statistical probability evidence, I would reverse on this basis also.

Section 10-915 does not endorse or validate any specific methodology, i.e., the product rule or the ceiling principle, by which the probabilities of a random match are to be computed. Consequently, the petitioner is also correct - before the results of calculations based on any such methodology may be admitted into evidence, the methodology must meet the Frye-Reed standard of general acceptance in the relevant scientific community.

Determining the applicability and scope of § 10-915 is a matter of statutory construction, the object of which is to discern and effectuate the Legislature's intent. Baltimore v. Cassidy,

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> 1/N, N being the number of entries in the databank....*The key question underlying the use of the multiplication rule--i.e., whether actual populations have significant substructure for the loci used for forensic typing--has provoked considerable debate among population geneticists*.

Id. at 2-9- 2-11. (Emphasis added).

338 Md. 88, 93, 656 A.2d 757, 760 (1995). The source of legislative intent ordinarily is the language of the statute itself. Harris v. State, 331 Md. 137, 145, 626 A.2d 946, 950 (1993). "In the interest of completeness,..., we may look at the purpose of the statute and compare the result obtained by use of its plain language with that which results when the purpose for the statute is taken into account," id. at 146, 626 A.2d at 950; "however, the statute must be interpreted reasonably, avoiding an interpretation that is illogical or incompatible with common sense." D & Y, Inc. v. Winston, 320 Md. 534, 538, 578 A.2d 1177, 1179 (1990); Blandon v. State, 304 Md. 316, 319, 498 A.2d 1195, 1196 (1985); Erwin & Shafer, Inc. v. Pabst Brewing Co., 304 Md. 302, 315, 498 A.2d 1188, 1194 (1985).

Section 10-915(b) expressly provides that DNA profile evidence is admissible "to prove or disprove the identity of any person." In addition, however, the statute provides that, before such evidence is admissible several discovery and notice requirements must be met. "The party seeking to introduce the evidence of DNA profile" is required to provide written notice of that intention at least 45 days before any criminal proceedings. § 10-915(b)(1). Under § 10-915(b)(2)(v), the proponent of DNA profile evidence must submit to the other side "[a] statement setting forth the allele frequency and genotype data for the appropriate data base utilized." This requirement is triggered by a written request from the opponent of the evidence. The majority maintains that this

single reference to a statement of allele frequency and genotype data evidences the Legislature's intention that statistical probability evidence be admissible as DNA profile analysis evidence.

It is well settled that simply because evidence is discoverable does not mean that it is admissible. Patrick v. State, 329 Md. 24, 30, 36, 617 A.2d 215, 218, 221 (1992). Indeed, the test for discoverability is quite different from the test for admissibility. See Md. Rule 2-402(a) which, as relevant, provides:

> It is not ground for objection that the information sought is already known to or otherwise obtainable by the party seeking discovery or to the claim or defense of any other party. It is not ground for objection that the information sought appears reasonably calculated to lead to the discovery of admissible evidence.

It seems obvious that the disclosure requirement was included in § 10-915 in order to ensure that the party against whom the proffered DNA evidence is produced has access to information helpful, or necessary, to challenge the accuracy of the laboratory testing procedures used and the reliability of the results produced. See generally Sommers v. Wilson Bldg. & Loan Ass'n, 270 Md. 8, 174 A.2d 776 (1973). Had the General Assembly intended another purpose - that the statement of allele frequency and genotype data be admissible as DNA profile evidence - it could have and, I submit, would have clearly so provided. The Legislature certainly knows how to do so. Section 10-915(2)(b)(v) does not prescribe the method to be utilized in determining the statistical probability of

a "match" between the evidentiary DNA and that of the defendant. This is further evidence that the statement of allele frequency and genotype data is not intended routinely to be admitted along with other DNA "match" evidence. It can not be assumed, as the majority seems to do, that the Legislature intended that any and all statistical methodologies purporting to determine the probability of a random match be per se admissible.

That a DNA profile analysis, using the restriction fragment length polymorphism process, results in a "match" does not necessarily mean that the evidentiary DNA and the defendant's DNA sample came from the same person. It may mean only that two persons, including the one from whom the sample was taken, have the same allele at the locus probed by a particular restriction enzyme. The likelihood of that occurrence can be estimated statistically by computing the probability that someone chosen at random will have the same allele at the same locus as the person whose sample DNA is being tested. NRC Report at 2-10. This is done by estimating the frequency with which the subject allele occurs in the general population. Id.

With this in mind, the majority argues that statistical probability evidence is necessary to the jury's understanding of the DNA profile evidence. To interpret § 10-915 otherwise, it maintains, "would provide juries with DNA evidence that they could not evaluate in a logical manner." Armstead, ___ Md. at ___, ___ A.2d at ___ [slip op. at 47]. To be sure, that conclusion has been

reached by some courts that have considered the matter. See e.g. Lanigan, 596 N.E.2d at 314. Other cases have reached the opposite result. See e.g. Com. v. Crews, 640 A.2d 395, 403 (PA 1994); State v. Kim 398 N.W.2d 544, 548-49 (Minn. 1987). See also Houser, 290 N.E.2d at 183; Curnin, 565 N.E.2d at 442-45; Boyd, 331 N.W.2d at 482-83; Perry. 586 So.2d at 254. In Crews, the court admitted "raw" DNA evidence, but excluded statistical probability estimates, reasoning, "The factual evidence of the physical testing of the DNA samples and the matching alleles even without statistical conclusions, tended to make appellant's presence more likely than it would have been without the evidence, and was therefore relevant." Id. at 402. In Kim, the court also admitted "raw" DNA evidence, but excluded proffered statistical evidence on the grounds that if the expert were permitted to express an opinion as to the source of the DNA sample at issue, "a jury will naturally convert [the statistical probability estimate] into an inclusion percentage." Id. at 548. I find these cases more persuasive. I also find it significant that § 10-915 does not establish a threshold statistical probability level, below which such evidence is inadmissible. Including such a provision in a statute, in addition to evidencing an intention that probability evidence be admissible, would also establish criteria for measuring the reliability of that evidence. See § 5-1029 of the Md. Family Law

Code Ann. (1984, 1991 Repl. Vol.).[9] Its absence, in my opinion, greatly undermines the majority's assertion that random match statistics are necessary to understanding DNA profile evidence.

In any event, the statute is anything but crystal clear; it is at the very least ambiguous on the question of its breadth. In such cases, it is well settled that the rule of lenity applies and that the statute must be construed in the light most favorable to the defendant.

Even if the majority were correct, that the statistical probability analysis is a necessary part of the DNA profile analysis evidence, and I do not concede that it is, the admissibility of that evidence remains subject to the requirements of Md. Rules 5-702 and 5-403. In regard to the former, there are several issues which must be considered: (1) whether the product rule is a statistical methodology that is generally accepted in the relevant scientific community; (2) whether the reference data base which it utilizes is an "appropriate data base," as § 10-915(b)(2)(v) requires; and (3) whether it fulfills its purported

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[9] Section 5-1029 provides:

(e) Laboratory report as evidence.--

(1) Subject to the provisions of paragraph (3) of this subsection, the laboratory report of the blood or genetic test shall be received in evidence if:

(i) definite exclusion is established; or
(ii) the testing is sufficiently extensive to exclude 97.3% of alleged fathers who are not biological fathers, and the statistical probability of the alleged father's paternity is at least 97.3%

purpose of accurately determining the probability of a random match. In answering the last question, the Cellmark .07% laboratory error rate must be considered.

Balancing the probative value of the product rule principle against its prejudicial effect, involves the issue of its reliability, i.e., whether the data base utilized is an appropriate one and whether the relevant laboratory error rate is included in the calculation. Furthermore, the extent to which the jury may be misled, or confused, to the prejudice of the defendant, by being informed of three different, yet unrelated, statistics concerning the odds of a random match must also be considered, as must the jury's inclination to use the product rule calculations to determine the likelihood of the defendant's guilt or innocence. Boyd, 331 N.W.2d at 483 (court explained that the potential prejudice against which the probative value of DNA profile evidence must be weighed, derives from the "real danger that the jury will use the evidence as a measure of the probability of the defendant's guilt or innocence, and that the evidence will thereby undermine the presumption of innocence, erode the values served by the reasonable doubt standard, and dehumanize our system of justice." (citations omitted)).

I respectfully dissent. In my opinion, the petitioner is entitled to a hearing to consider the admissibility of the DNA profile evidence, followed by a new trial.