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PARENTAGE TESTING: AN INTERFACE BETWEEN MEDICINE AND LAW

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I. HISTORICAL PERSPECTIVES

The most famous early reference to disputed parentage appears in the Old Testament,¹ where Solomon makes the choice of maternity by threatening to use his sword to provide each claimant with a portion of the child. Aside from illustrating Solomon's acumen in solving problems, this story has all the elements that face the trier of fact when there is no witness to the event and perjury is likely. Although in Solomon's case maternity was at issue, more commonly the question is one of paternity. Establishing paternity is critical because of the numerous legal rights associated with the relationship, ranging from inheritance and insurance to support obligations and governmental benefits.

Modern science has provided new tools to assist in the objective determination of disputed parentage. Current social policies and judicial decisions set the parameters within which these

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1. 1 *Kings* 3:16-27.

tools can operate, with a view toward the important legal rights that flow from the adjudication of a biologic relationship. "Public policy mandates the use of the most reliable and objective evidence available to determine the parentage of a child whose interests are at stake in a disputed paternity proceeding."²

In a landmark 1968 decision, the United States Supreme Court first invalidated discrimination against illegitimate children on equal protection grounds.³ As the Court held in a subsequent decision, "The status of illegitimacy has expressed through the ages society's condemnation of irresponsible liaisons beyond the bonds of marriage. . . . Obviously, no child is responsible for his birth and penalizing the illegitimate child is an ineffectual — as well as an unjust — way of deterring the parent."⁴ Other Supreme Court decisions have ensured that in most respects the child born out of wedlock may not be treated differently by virtue of that status.⁵

In addition, statutory mechanisms have been enacted to encourage the establishment of parentage. Amendments to the Social Security Act in 1975 created a comprehensive plan for providing aid to needy families with children that included provisions for establishing paternity.⁶ The legislation provided federal funding to the states for child support enforcement and led to the formation of state programs and agencies often referred to by the designation IV-D. Several model acts provide guidance to the states with respect to paternity proceedings.⁷

Although at one time courts were reluctant to admit any scientific evidence relative to paternity testing, a majority of states have either legislatively or judicially established the admissibility of exclusionary genetic tests.⁸ As one state appellate court recently

2. *Everett v. Everett*, 150 Cal. App.3d 1053, 1065, 201 Cal. Rptr. 351, 357 (1984).

3. *Levy v. Louisiana*, 391 U.S. 68, 72 (1968) (legitimacy of children had no relation to the wrong inflicted on them by the wrongful death of their mother).

4. *Weber v. Aetna Casualty & Surety Co.*, 406 U.S. 164, 175 (1972) (denial of equal recovery rights under workmen's compensation statute to unacknowledged illegitimate children violates the equal protection clause of the fourteenth amendment).

5. *See, e.g., Trimble v. Gordon*, 430 U.S. 762, 776 (1977) (state statute which allows illegitimate children to inherit by intestate succession from their mother but not from their father violates equal protection clause of the fourteenth amendment); *Gomez v. Perez*, 409 U.S. 535, 538 (1973) (state may not deny illegitimate children the right to paternal support while granting it to legitimate children). *But see Lalli v. Lalli*, 439 U.S. 259, 275-76 (1978) (state statute allowing illegitimate children to inherit from intestate father only if a court of competent jurisdiction had entered an order declaring paternity during the father's lifetime was substantially related to important state interests in providing for the just and orderly disposition of property at death, and thus did not violate the equal protection clause). *Cf. Parham v. Hughes*, 441 U.S. 347, 353 (1979) (state statute precluding father from suing for wrongful death of illegitimate child does not violate the equal protection clause since father could have legitimated child and chose not to do so).

6. 42 U.S.C. § 602(a) (26) (B) (1982). As a condition of eligibility for aid each applicant is required to cooperate with the state in establishing the paternity of a child born out of wedlock with respect to whom aid is claimed, *Id.*

7. *See, e.g., UNIF. PARENTAGE ACT*, 9A U.L.A. 579, §§ 11, 12 (Supp. 1984).

8. *See Comment, Blood Test Evidence in Disputed Paternity Cases: Unjustified Adherence to the*

noted, "blood-test procedures provide the most reliable means for making the determination of paternity more accurate and efficient."⁹ The United States Supreme Court has held that an indigent defendant in a paternity action has a due process right to blood-group testing at public expense.¹⁰

Despite the recognition of the importance of blood-group testing and the adoption of the Uniform Parentage Act by a number of states, many jurisdictions remain unwilling to admit scientific evidence tending to establish paternity.¹¹ The scientific acceptance of modern genetic tests, however, based upon their reliability and validity when properly performed, provides persuasive argument for the judicial recognition of inclusionary tests as well.

The role of modern science in questions of disputed parentage began with the discovery of the ABO blood groups by Karl Landsteiner in 1900. The recognition that these objectively measured characteristics in man followed the genetic rules discerned by Gregor Mendel is the cornerstone of all that has followed. Mendel, an Austrian monk, observed that certain characteristics of the common garden pea could be predicted based on which parental strains were used to produce the next generation of plants. Testing of unrelated individuals (random populations) showed that the ABO characteristics are polymorphic, distributed

Exclusionary Rule, 59 WASH. U.L.Q. 977, 1006 n.187 (1981). States that statutorily allow the use of exclusionary genetic tests include: Alabama (ALA. CODE § 26-12-5 (1975)); Arkansas (ARK. STAT. ANN. § 34-705.1 (1962)); California (CAL. EVID. CODE § 895 (Deering 1966)); Connecticut (CONN. GEN. STAT. § 46b-168 (1979)); Idaho (IDAHO CODE § 7-115 (1979)); Illinois (ILL. ANN. STAT. ch. 40, § 1401 (Smith-Hurd 1980)); Maryland (MD. ANN. CODE art. 16, § 66G (1981)); Massachusetts (MASS. ANN. LAWS ch. 273, § 12A (Michie/Law Co-op 1980)); Michigan (MICH. STAT. ANN. § 25.496(d) (1974)); Mississippi (MISS. CODE ANN. § 93-9-27 (1972)); New Jersey (N.J. STAT. ANN. § 2A: 83-2, -3 (West 1976)); New York (N.Y. JUD.-CT. ACTS LAW § 532 (McKinney Supp. 1980)); Ohio (OHIO REV. CODE ANN. § 3111.16 (Page 1980)); Oklahoma (OKLA. STAT. ANN. tit. 10, § 504 (West Supp. 1980)); Pennsylvania (42 PA. CONS. STAT. ANN. § 6136 (Purdon Supp. 1981)); Tennessee (TENN. CODE ANN. § 36-228 (1977)); and West Virginia (W. VA. CODE § 48-7-8 (1980)). Three states have judicially established the admissibility of exclusionary genetic tests: Florida (Simons v. Jorg, 375 So.2d 288 (Fla. Dist. Ct. App. 1979)); Missouri (T.A.L.S. v. R.D.B., 539 S.W.2d 737 (Mo. Ct. App. 1976)); and South Dakota (State ex rel. Wollock v. Brigham, 72 S.D. 278, 33 N.W.2d 285 (1948)). Comment, *supra*, at 1006 n. 187.

9. State ex rel. Orloff v. Hanson, 277 N.W.2d 205, 206 (Minn. 1979) (it is not improper for a party to elicit evidence that the other party refused to submit to blood testing). Accord Machacek v. Voss, 361 N.W.2d 861 (Minn. 1985) (upholding constitutionality of a statute permitting the court to order an alleged father whose likelihood of paternity was determined by blood tests to be over 92% to pay temporary child support).

10. Little v. Streater, 452 U.S. 1 (1980). The Court has also invalidated one and two year limitation periods for paternity claims. See Pickett v. Brown, 462 U.S. 1, 18 (1983) (statute fails to provide adequate opportunity to obtain support and was not substantially related to state interest in avoiding stale or fraudulent claims); Mills v. Habluetzel, 456 U.S. 91, 100-01 (1982) (statute fails to provide reasonable opportunity to assert claims for support and is not substantially related to state interest in preventing litigation of stale or fraudulent claims).

11. See Comment, *supra* note 8, at 1005. These courts stated that only testing that excludes the alleged father is conclusive and that the admission of inconclusive inclusionary test results unfairly prejudices the jury. *Id.* See also Terasaki, *Resolution by HLA Testing of 1,000 Paternity Cases Not Excluded by ABO Testing*, 16 J. FAM. L. 543, 543 (1978).

in the population so that there are differences between individuals and the occurrence of these differences is similar from one generation to the next. It was also shown that testing within families produced predictable patterns of the ABO types in the children when the parents' groups were known. From these observations it was possible to establish that certain types of matings could not result in certain types of children.¹² In the 1920s the first papers utilizing these scientific facts to prove non-paternity appeared.

It was many years after Landsteiner's discovery of ABO before another red cell system was recognized, but in the last twenty years a great number of polymorphic genetic systems have been discovered, including those of proteins, enzymes, and tissue antigens (HLA - human leukocyte antigens). As these advances in science were being reported, the American Medical Association (AMA) established a Committee on Medicolegal Blood Grouping Tests. Periodically, this group prepared reports evaluating the use of various genetic tests in disputed paternity, recommending model laws, and discussing the qualification of experts in this field.¹³

In 1938 the question of the alternative result from paternity testing, namely where the tested man is not excluded, was addressed by E. Essen-Moller, who suggested using a likelihood ratio to estimate how probable it was that the not-excluded tested man was the father. Though the use of inclusion probabilities has been common in Europe, their acceptance in the United States is a recent development.

In 1971, at the request of the American Bar Association's Section on Family Law, a joint ABA-AMA committee was formed to produce guidelines for both the medical and legal professions in matters of disputed parentage.¹⁴ This document, published in 1976, made suggestions on the extent of testing, the systems to be

12. The following table illustrates the results of matings for some of the possible phenotypes in the ABO system:

MATING	CHILDREN POSSIBLE	NOT POSSIBLE
A x A	A, O	B, AB
A x B	A, B, O, AB	--
A x O	A, O	B, AB
O x O	O	A, B, AB

The reader should note that a person with the phenotype A can be of the genotype AA or AO but O is always OO. See Selvin, *Some Statistical Properties of the Paternity Ratio*, INCLUSION PROBABILITIES IN PARENTAGE TESTING 77, 79 (Table 9-1) (R.H. Walker ed. 1983).

13. The first of these reports appeared in 1937. It consisted of recommendations made by the committee members, Ludvig Hektoen, Karl Landsteiner and Alexander Wiender. Jennings, *AMA Interest in Parentage Testing - Historical Perspective*, INCLUSION PROBABILITIES IN PARENTAGE TESTING, 21, 21 (R.H. Walker ed. 1983).

14. *Joint AMA-ABA Guidelines: Present Status of Serologic Testing in Problems of Disputed Parentage*, 10 FAM. L. Q. 247, 247 (1976) [hereinafter cited as *Guidelines*].

used, and the application of results to include as well as exclude the tested man.¹⁵ In May of 1982 a conference entitled "Inclusion Probabilities in Parentage Testing" sponsored by the American Association of Blood Banks (AABB), the AMA, and the ABA resulted in the publication of "Guidelines for Reporting Estimates of Probability of Paternity."¹⁶ The first of these guidelines sets forth the underpinning of our current approach to paternity testing:

Testing of genetic markers in cases of disputed parentage should include multiple systems which will exclude most falsely accused men. If tests fail to exclude the alleged father, an estimate of the probability of paternity should routinely be calculated from the observed phenotypes of the mother, child and alleged father.¹⁷

In 1984 these guidelines were incorporated in a more extensive document entitled "Standards for Parentage Testing Laboratories," which is the basis for a program to accredit laboratories offering parentage testing services.¹⁸

II. GENERAL PRINCIPLES OF GENETIC MARKER TESTING

The general principles that form the basis for applying tests of genetic markers to cases of disputed parentage include the following:

1. One-half the genetic information in a child is maternal in origin and one-half is paternal in origin.
2. Only one man can be the biologic father of a child and a sperm containing one-half the genetic information present in this individual fertilized the ovum containing one-half the genetic information of the biologic mother.¹⁹
3. The marker studied is established as a product of genes which obey Mendel's Laws of Inheritance so that:

15. *Id.*

16. INCLUSION PROBABILITIES IN PARENTAGE TESTING, at xiv (R.H. Walker ed. 1983). On the basis of these guidelines, which have been approved by the AMA and the ABA Section of Family Law, a set of standards to accredit laboratories doing parentage testing has been developed by the AABB with participation from other interested organizations.

17. *Id.*

18. AMERICAN ASSOC. OF BLOOD BANKS, STANDARDS FOR PARENTAGE TESTING LABORATORIES (1984).

19. *But cf.* Terasaki, Gjerfson, Bernoco, Perdue, Mickey, & Bond, *Twins With Two Different Fathers Identified By HLA*, 299 NEW ENG. J. MED. 590 (1978) (in the case of nonidentical twins there can be more than one father).

- a. a child cannot have a genetic marker that is absent in both parents;
 - b. a child must inherit one of a pair of markers from each parent;
 - c. a child cannot have a pair of identical genetic markers unless both parents have the marker;
 - d. a child must have a genetic marker if it is present as an identical pair in one parent.
4. The test method used must be reliable and reproducible and measure an inherited characteristic.
 5. The genetic system must be polymorphic (marker frequency varies within the population) and the gene frequencies must be established by examination of an appropriate sample of the random population.
 6. The genetic systems used in calculating inclusion and exclusion probabilities should segregate independently (the finding of a marker in one system is not dependent on the presence or absence of a specific marker in another genetic system).

III. WHAT IS THE CHANCE OF EXCLUDING A FALSELY ACCUSED MAN?

The current state of the art in paternity testing makes it possible to find evidence of nonpaternity more than ninety-five percent of the time when the tested man is not the father of the child in question. Several approaches can be used to reach this probability of exclusion. As indicated in the guideline quoted above, a combination of genetic systems should be used; the choice of systems is made by each laboratory.

Based on the distribution of the markers in the population a power of exclusion can be calculated for a genetic system. One can estimate the chance that a man chosen at random would not have the gene necessary to explain the paternal contribution in a given child when the mother's contribution is known. Taking into account all the possible combinations for a system, one can assign a mean probability of exclusion for that system. As more independent systems are tested, the cumulative probability of exclusion (CPE) is increased. It must be remembered that as each additional system is tested, a certain percentage of nonfathers will have been excluded by the prior test. Thus, the chance of an additional test proving nonpaternity is limited to the fraction of

nonfathers who have not been excluded.²⁰

If, after undergoing a battery of tests that on the average will exclude ninety-five percent of nonfathers, an accused man is not excluded, it is possible that doing another test will prove nonpaternity if he is not the father. Conversely, intuition tells us that if there is a high probability of reaching a conclusion after doing a test and we fail to reach that conclusion (proof of nonpaternity), it is likely that the alternate hypothesis (paternity) is true. A problem with this line of reasoning is that it ignores the fact that CPE is just an average and in an individual case could be misleading, particularly if the biologic father of the child is a first degree relative (father, brother, or son) of the tested man.

Proof of nonpaternity is established when the test results in one or more systems fail to meet the criteria of Mendel's Laws. Exclusions²¹ may be direct (the presence in the child of a marker that is absent in both the presumed mother and the tested man) or indirect (failure to find an expected marker in the child when the tested man appears to have an identical pair of genes). In reaching a conclusion of nonpaternity based on failure to find an expected marker in the child (indirect exclusion), one must consider the possibility that both the tested man and the child have a gene product that cannot be detected by our current test methods. In almost all genetic systems there is the possibility of a "null" gene or a gene that makes no detectable product (amorph). In most systems used these are rare; however, in some cases additional tests on the trio (alleged father, presumed mother, child) or on other relatives may be needed to decide if the findings exclude or include the parent in question.

IV. CAN PATERNITY BE PROVEN BY GENETIC MARKER TESTS?

The answer to this question is a qualified no. The sophisticated tests available today cannot prove paternity, but can give an estimate that the nonexcluded tested man could be the father. In the future new methods directed at testing of inherited variations of the structure of the DNA that makes up the genes may provide a specific way to establish unique sequences that specifically identify the parents of a child.

20. The mathematical formula used to find the cumulative probability of exclusion is: $CPE = 1 - (1 - P_1)(1 - P_2) \dots (1 - P_n)$. See *Guidelines, supra* note 14, at 258. In this formula, P₁, P₂ and P_n stand for the means probabilities of individual exclusions. *Id.*

21. The following table represents examples of exclusion types based on testing the Gc protein system by isoelectric focusing:

Estimating the possibility of paternity depends on establishing the most probable maternal and paternal contribution to the child and comparing the likelihood that the paternal marker (X) was passed by the tested man as compared to the frequency of that marker in the population of possible fathers. Since we are testing an individual who has been accused by the mother and have no way of testing the universe of possible fathers, we must depend on values for the frequency of the gene in the random population (Y). In most systems determining the value of X is easy. If the alleged father is homozygous (both genes identical), then he will always pass the same genetic information to his offspring and $X = 1.0$. If the alleged father is heterozygous (has two different genes, only one of which can account for the paternal marker in the child) then the chance he will pass the appropriate genetic information is one-half and $X = 0.5$. This explanation is a simplification of the actual calculations²² which also consider the maternal contribution and may include an estimate of genotype (the actual genes present in an individual) from the phenotype (the marker(s) determined by the test).

The gene frequency in the population, Y, is determined from tables based on testing a sample of the population.²³ These frequencies vary in different racial groups.²⁴ The reliability of the values in the frequency tables depends on having a large enough sample so that the estimate of the error for the values is small.²⁵ In genetic systems in which there are only a few alleles (alternative

	Tested Man	Mother	Child	Type of Exclusion
Phenotype	lslf	ls	ls2	Direct
Genotype	lslf	lsls	ls2	
Phenotype	2	lslf	lslf	Direct
Genotype	22	lslf	lslf	
Phenotype	lf	ls2	ls	Indirect
Genotype	lflf or lf "x"	ls2	lsls or ls "x"	

("x" is used to represent a possible null gene).

22. The following table illustrates the calculation of the paternal contribution (X) for determining the likelihood ratio (x/y):

Tested Man	Phenotype Mother	Child	Expected Paternal Gene	X
ab	b	ab	a	0.5
a	b	ab	a	1.0
a	ab	ab	a or b	1.0
a	ab	b	b	0

23. Dykes, *The Use of Frequency Tables in Parentage Testing*, PROBABILITY OF INCLUSION IN PATERNITY TESTING 15, 16 (H. Silver ed. 1982). The author states that sample sizes of 200-500 provided adequate results. *Id.* at 17.

24. *Id.* The author stated that although there were racial differences for many of the marker systems, there were no consistent or significant differences in intraracial variation based on geographical variation. *Id.* at 16.

25. *Id.* at 15.

genes at the same locus) and these are evenly distributed in the population, a sample of a few hundred individuals will provide a good estimate of the true frequencies. In systems in which there are numerous alleles and most have a low frequency, a much larger sample is needed to get an accurate estimate of the gene frequencies. The ratio of X/Y is known as the likelihood ratio or gene system index. This value indicates the chance that a man with the phenotype observed for the alleged father could pass the paternal gene compared to men in the random population.

A summary of the test results in several systems can be calculated by multiplying the X/Y values for each system that is independent of the others. This figure is the paternity index (PI), which is the genetic odds in favor of paternity given the phenotypic observations on the tested trio. Another way of presenting the genetic results is to calculate a likelihood of paternity.²⁶ This expression combines the genetic information with the nongenetic information — the assumption that the nonexcluded tested man had the opportunity to father the child. The nongenetic information is referred to as the prior probability. Combining the nongenetic information with the genetic information (test results expressed as the PI) gives a posterior probability, which is a percentage called the likelihood of paternity. This calculation is based on Bayes Theorem and requires choosing a value for the prior probability. Because the testing laboratory does not have knowledge of the nongenetic factors in the case, most experts use a neutral or fifty percent prior in their calculation.

The likelihood value (W) compares the chance of the tested man with one other man in the random population who is assumed to have had an equal chance to have fathered the child. Other values can be used for the prior probability. In theory, if there are several men who had access at the appropriate time or if the frequency of intercourse with two possible fathers was disparate, then changing the prior would give weight to the nongenetic information when only one of the men has been tested. In our opinion, using a prior other than 0.5 ignores the biologic fact that it takes only a single sperm to fertilize the ovum and that a man either is or is not the father.

26. The following equation is used to determine the likelihood of paternity (W):

$$w = \frac{(x/y)p}{(x/y)p + (1 - p)}$$

x/y is the paternity index. p is the prior probability when p = 0.5, W =

$$\frac{PI}{PI + 1}$$

V. WHAT GENETIC SYSTEMS SHOULD BE TESTED?

Currently there are as many as thirty different genetic systems used by various laboratories doing paternity testing. In practice, only a small group of these tests is needed routinely to exclude more than ninety-five percent of falsely accused men or to obtain a paternity index that is sufficient to establish paternity if the nongenetic facts support the mother's allegation. Each of the various genetic systems has certain advantages as well as disadvantages. Not only does the exclusion power of each system differ, but also the storage characteristics of the markers and the cost of testing vary greatly.

Traditionally, testing in cases of disputed parentage was limited to a few red cell antigen systems. Prior to 1975 very few laboratories in the United States did more than test for ABO, Rh, and MNSs.²⁷ The CPE for these three red cell antigen systems is fifty-seven percent in caucasians. In 1976 many more systems including the red cell antigen systems Kell, Duffy (Fy), and Kidd (Jk) and the HLA system (a group of tissue antigens found on the lymphocytes) became fairly routine in paternity testing. Adding these systems increased the CPE to more than ninety percent. Another way to achieve a CPE of more than ninety percent is to combine the red cell antigen systems with various protein and red cell enzyme markers.²⁸

The tests for red cell antigens depend on observing agglutination (a clumping together) of the red cells when they are mixed with an antibody that reacts with the marker expressed on the cell membrane. These tests are quite reliable when done by trained personnel and are used in preparing blood for transfusion to patients. The genetics of these systems and the biochemistry of many of the antigens are well established.²⁹ Data is available on the frequencies of these markers in most populations. Samples for red cell antigen testing can be sent to the testing facility by mail and most of these markers are stable for several weeks if properly stored.

The serum protein and red cell enzyme (proteins found in the red cell that react with specific substrates) systems are tested by

27. Polesky & Krause, *Blood Typing in Disputed Paternity Cases — Capabilities of American Laboratories*, 10 FAM. L. Q. 287, 291 (1976).

28. Polesky, *New Concepts in Paternity Testing*, 4 DIAGNOSTIC MED. 49 (1981). See also Dykes & Polesky, *The Usefulness of Serum Protein and Erythrocyte Enzyme Polymorphisms in Paternity Testing*, 65 AM. J. CLIN. PATHOL. 982, 986 (1976); Dykes & Polesky, *Properdin Factor B (BF) as an Exclusion Determinate in Parentage Testing*, 30 HUMAN HERED. 286, 289 (1980); Dykes, Polesky, & Cox, *Isoelectric Focusing of Gc (Vitamin D) Binding Globulin in Parentage Testing*, 58 HUMAN GENET. 174, 175 (1981).

29. See generally R. R. RACE & R. SANGER, *BLOOD GROUPS IN MAN* (6th ed. 1975).

placing the sample on a supporting material and separating the markers in an electric field. The basic principle of these tests is that the inherited protein molecules vary in charge depending on their genetically determined amino acid composition. By selecting the proper test conditions one can separate molecules with minimal differences in structure. These tests are quite reliable and depending on the marker are not likely to be altered by storage and/or shipping. The recent development of isoelectric focusing, a technique that separates molecules in a pH gradient, has increased the power of exclusion and hence the usefulness of several of the protein and enzyme markers systems.³⁰ These electrophoretic tests have been widely used in forensic laboratories to identify characteristics in blood stains. As with the red cell antigens, the genetics, the population distribution, and the biochemical structure have been worked out for these markers.

The most powerful single genetic system currently available is the HLA system.³¹ The identification of over sixty-five HLA-A, -B antigens makes this the most polymorphic system that has been defined in man. In addition to the multiple antigens, the pattern of inheritance of a combination of A and B from each parent in the form of a haplotype adds to the diversity seen in this system. This combination of antigens from each parent occurs because the genes coding for the HLA-A, -B antigens are part of a closely associated portion of chromosome six that is usually inherited as a unit.³²

The tests for HLA antigens depend on observing the killing of lymphocytes by antibodies directed to the genetic markers on their surface. This test, known as lymphocytotoxicity, is highly specific when done properly. The conditions for testing are rigid and include having living cells in the test system. Samples for HLA must reach the testing facility within a specified period of time so that living lymphocytes from the person being tested can be harvested from the blood. In this testing a very large panel of antisera is required to determine which markers are present. Because most of the reagents used in this system are not pure, that is, they often will react with more than one antigen, and because the amount of cell death observed is variable, samples from each member of the trio should be tested at the same time.

30. Dykes & Polesky, *Review of Isoelectric Focusing for Gc, PGM1, Tf and Pi Subtypes: Population Distributions*, 20 CRC CRITICAL REVIEW IN CLINICAL LABORATORY SCIENCES 115 (1984). See also Dykes & Polesky, *Isoelectric Focusing of PGM1 (E.C.2.7.5.1) on Agarose: Application to Cases of Disputed Parentage*, 75 AM. J. CLIN. PATHOL. 708, 710 (1981).

31. In this system, H stands for human, L for leukocyte, and A for antigen. Terasaki, *supra* note 11, at 545.

32. THEORETICAL ASPECTS OF HLA (E. Hackel & D. Mallory, eds. 1982). See also Terasaki, *supra* note 11, and R.H. Walker, *supra* note 16, at 297, 305, 325, 371.

Analysis of the results of HLA tests when they fail to exclude depends on having a frequency table of the haplotypes in the random population (Y) to compare with the chance the tested man passed the paternal haplotype (X). The great diversity of these antigens in the population means that the frequencies of the various haplotypes are small and that there is a larger error in estimating the frequency value when the haplotype is unusual. Calculating X is also more difficult, because one has to account for the chance that the haplotype in the tested man is or is not the paternal haplotype in the child.

VI. LEGAL CONSIDERATIONS IN THE INTRODUCTION OF GENETIC TESTS

Once genetic testing has been performed, problems of admitting the test results into evidence may still remain. As noted above, some courts are still unwilling to admit test results that do not exclude paternity or test results based on newer genetic systems. To the extent that this reluctance is based upon the *Frye*³³ rule making acceptance by the scientific community the criterion for admissibility of scientific evidence, the strong scientific acceptance of HLA and serum protein and red cell enzyme systems argues persuasively for their judicial acceptance.³⁴ Where inclusionary results are admissible, further questions may still arise about the admissibility of the expert's statistical calculation of probability of paternity.³⁵ Even if the court is inclined to admit the test results, the proponent must still establish an adequate foundation. Appropriate identification of the blood samples as drawn from the individuals involved and proper storage and handling of the blood once drawn are two critical elements in laying an adequate foundation. Other important foundational

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

34. For holdings on the admissibility of HLA, see, e.g. *Cramer v. Morrison*, 88 Cal. App. 3d 873, 153 Cal. Rptr. 865 (1979) (results of HLA testing are highly probative and therefore relevant); *Malvasi v. Malvasi*, 167 N.J. Super. 513, 401 A.2d 279 (1979) (HLA testing is recognized by the scientific community as reliable, accurate, and highly probative on the issue of paternity).

35. The Uniform Parentage Act, § 12 (3), allows evidence of statistical probability, but it has been adopted in only a minority of jurisdictions. These jurisdictions include California (WEST'S ANN. CAL. CIV. CODE §§ 7000-7018 (West 1983)); Colorado (COLO. REV. STAT. §§ 19-6-101 to -129 (1978 & Supp. 1984)); Hawaii (HAWAII REV. STAT. §§ 584-1 to -26 (1976 & Supp. 1983)); Minnesota (MINN. STAT. ANN. §§ 257.51 — .74 (West 1982 & Supp. 1985)); Montana (MONT. CODE ANN. §§ 40-6-101 to -135 (1983)); Nevada (NEV. REV. STAT. §§ 126.011 — .391 (1983)); New Jersey (N.J. REV. STAT. §§ 9:17-38 to -59 (Supp. 1984)); North Dakota (N.D. CENT. CODE §§ 14-07-01 to -26 (1981 & Supp. 1983)); Washington (WASH. REV. CODE ANN. 26.26.010 — .905 (Supp. 1985)); and Wyoming (WYO. STAT. §§ 14-2-101 to -120 (1977)). Cf. *State v. Boyd*, 331 N.W.2d 480 (Minn. 1983) (even in a jurisdiction allowing statistical probabilities in paternity actions, statistical evidence prohibited in prosecution for criminal sexual conduct with respect to showing that defendant fathered victim's child).

considerations for the proponent of the tests include showing that the tests were properly performed and that the persons who performed the tests, interpret, and testify about them are appropriately qualified.³⁶

Although going more to the weight of the evidence than to its admissibility, a number of other questions may be raised by the party opposing the tests. These include the possibility of rare alleles or mutation (spontaneous change in the genetic information), the possibility of laboratory error, and the fact of gene frequency variation among different population groups. These questions may need to be addressed by the expert. Rare alleles are usually only a problem when there is a single indirect exclusion. Mutation of the genes coding for the markers used in parentage testing is possible; however, it is such a rare event (rate less than one in a million) that well documented examples are not available. Laboratory error is always possible since humans are involved in doing the tests and recording the results. To avoid laboratory error, a system of quality control including some duplication of testing and careful review of results should be used by the testing facility. Though there are racial differences in the frequencies of genes, when testing has been done in multiple systems and the man has not been excluded, the possible error from calculating a likelihood using a table that has been determined from a different population is very small.

Arguments disputing analytical systems and thus casting doubt on the statistical calculations involved may well confuse the trier of fact. It is important to remember that the test results provide only an estimate of paternity which the trier of fact must weigh with the nongenetic information such as access at the appropriate time.

VII. CONCLUSION

Despite the complexity of the scientific tests involved and despite the corresponding sophistication required of both the attorney and the trier of fact in this area, blood tests offer by far the most reliable means of ascertaining biologic parentage in cases of dispute. Indeed, it can be argued that the reliability of the tests has been so well accepted as to permit the introduction of certain test results under a business records exception to the hearsay rules

36. See Keith & Polesky, *Requisites for Introduction of Genetic Test Results in Paternity Trials*, in *PROBABILITY OF INCLUSION IN PATERNITY TESTING* (H. Silver, ed., 1982).

without requiring expert testimony.³⁷ In view of the critically important rights at stake for the child, the legal system's receptivity to the use of genetic tests must continue to be encouraged.

An appropriate summary of the issues we have discussed was written over thirty years ago by United States Supreme Court Justice Brennan, when he was a judge on the Appellate Division of the New Jersey Superior Court. Justice Brennan said:

[I]n the field of contested paternity . . . the truth is so often obscured because social pressures create a conspiracy of silence or, worse, induce deliberate falsity.

The value of blood tests as a wholesome aid in the quest for truth in the administration of justice in these matters cannot be gainsaid in this day. Their reliability as an indicator of the truth has been fully established.³⁸

37. *Id.* Cf. MINN. STAT. § 257.62(5) (Supp. 1983) (permitting an award of temporary child support upon test results indicating a likelihood of paternity in excess of 92%). The Minnesota Supreme Court recently upheld the constitutionality of this statute. See *Machacek v. Voss*, 361 N.W.2d 861 (Minn. 1985).

38. *Cortese v. Cortese*, 10 N.J. Super 152, 156, 76 A.2d 717, 719 (1950).