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Proving Paternity—Human Leukocyte Antigen Test

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ABSTRACT: The human leukocyte antigen (HLA) blood test is based on antigens (a substance that will stimulate the production of antibodies) found on the white blood cells. Because antigens are produced by genes, any HLA found in a child must be present in either parent. Thus, the HLA system of the blood of the child, mother, and putative father are tested and the probability of paternity is calculated. The HLA polymorphic genetic system is extremely powerful in determining the probability of paternity.

KEYWORDS: paternity, jurisprudence, genetic typing, human leukocyte antigen, tissue typing, blood grouping

Illegitimacy confronts the nation with serious problems. The birth rate of illegitimate children has risen dramatically. In the United States, of the 3 632 000 children born in 1950, 141 600 (4.0% of the total) were illegitimate children. Of the 3 327 000 children born in 1977, 515 700 (15.5% of the total) were illegitimate children [*1*]. It is apparent that liberalized abortion laws [*2*] and more effective birth control measures have not deterred the rise in illegitimate births.

A variety of factors may account for this phenomenon. In the last 20 years a significant number of couples have subscribed to the emerging trend of "living together" [*3*]. Many times these arrangements result in offspring. Other factors alleged to have contributed to the high illegitimacy rate are cultural-sexual permissiveness, diminishing social stigma attached to an unwed mother, lack of religious influence, decreased parental authority, urbanization and changing social values, and a "welfare" mentality [*4*]. Whatever the reasons may be for this drastic increase in illegitimate births, in view of the substantial costs involved in rearing a child to adulthood it is imperative that our legal system adopt some reliable approach to ascertain paternity. This would provide the child with two responsible parents, thereby lessening the possibility of the child's being placed on the welfare rolls of the state, and afford those men who are falsely accused a vehicle to prove their innocence. The recent advancements in genetic research have made it possible not only to exclude paternity but also to calculate the mathematical probability of paternity. The one test which has had the greatest impact in ascertaining paternity is the human leukocyte antigen (HLA) test [*5*]. By enlisting the use of such scientific techniques the courts can be assured of reaching the truth more efficiently.

Legal Rights of the Illegitimate Child

At common law the bastard was considered *filius nullius,* the son of nobody. The child had no rights of inheritance from his father or his mother [*6*]. Gradually the law began to

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recognize the relationship of the child to the mother, but the majority of states continued to have statutes that conscientiously discriminated against the illegitimate child and the substantive relationship to the father. Thus, in many areas such as support proceedings, inheritance by will or intestate succession, claims under wrongful death and survival statutes, workmen's compensation, social security benefits, and a variety of local, state, and federal welfare matters, the illegitimate child was precluded from asserting a right of claim [7].

The year 1968 marked the beginning of the United States Supreme Court's review of the constitutionality of statutes that purportedly discriminated against illegitimate children. In *Levy v. Louisiana* [8] the court handed down a decision declaring a Louisiana statute unconstitutional because it prohibited illegitimate children from recovering for the wrongful death of their mother. The court held the statute constituted invidious discrimination against illegitimate children and contravened their rights under the Equal Protection Clause of the Fourteenth Amendment. On the same day, the Court decided *Glona v. American Guarantee and Liability Insurance Co.* [9], a diversity action, and held that a Louisiana statute that barred a parent from recovering for the wrongful death of an illegitimate child while allowing the illegitimate child to recover for the wrongful death of a parent violated the Equal Protection Clause of the Fourteenth Amendment because there was no rational basis for the distinction.

Three years later, in *Labine v. Vincent* [10], the United States Supreme Court upheld a Louisiana intestate succession statute that allowed collateral relatives to take the decedent's property to the exclusion of his illegitimate daughter. The decedent had publicly acknowledged the child, but he failed to legitimize her. The court explained, unlike the *Levy* case, that the law did not constitute an insurmountable barrier to the illegitimate child. The father could have taken measures to provide for his daughter by leaving a will, marrying the child's mother, or by stating his desire to legitimize the child in his acknowledgment of paternity [10].

In *Weber v. Aetna Casualty and Surety Co.* [11] the Court struck down a Louisiana workmen's compensation statute that used a priority scheme that relegated dependent unacknowledged illegitimate children to a lesser status than "other dependents." The court stated, "The inferior classification of dependent unacknowledged illegitimates bore no significant relationship to those recognized purposes of recovery which workmen's compensation statutes commendably served."

In *Davis v. Richardson* [12] a Connecticut federal district court held a provision of the Social Security Act discriminated against illegitimate children since they were prohibited from receiving benefits derived from the death of a wage-earning parent if the family award was not sufficient to meet the maximum payments to the wife and legitimate children of the father. That the illegitimate child had been acknowledged or regularly supposed by the parent had no bearing on the result. The court held the act constituted an invidious discrimination against illegitimate children as a class. The United States Supreme Court summarily affirmed the decision on appeal [13].

In *Griffin v. Richardson* [14] a Maryland federal district court held a provision of the Social Security Act violative of the Fifth Amendment due process clause in that it discriminated against certain illegitimate children. Although the illegitimate child of the decedent qualified under the Social Security Act for benefits, another provision of the act excluded the child from obtaining benefits as long as there was a sufficient number of persons in a more favored class who exhausted the maximum family allowance.[2] On appeal, the decision of the lower court was summarily affirmed by the Supreme Court [15].

In 1973, the Supreme Court decided *Gomez v. Perez* [16]. The court held that a Texas law, which provided that legitimate children were entitled to parental support while illegitimate children were not, violated the Equal Protection Clause of the Fourteenth Amendment. The court went on to say, "Once a State posits a judicially enforceable right on behalf

[2]In the *Griffin* case [14], persons in the "favored class" were the products of the wife's previous relationships.

of children to needed support from their natural fathers there is no constitutionally sufficient justification for denying such an essential right to a child simply because its natural father has not married its mother."

In *New Jersey Welfare Rights Organization v. Cahill* [*17*] the Supreme Court held a New Jersey statute, which provided that the Assistance to Families of the Working Poor Program was to extend benefits only to those households composed of "two adults of the opposite sex ceremonially married to each other and [having] at least one minor child of both, the natural child of one and adopted by the other, or a child adopted by both," denied equal protection to illegitimate children. The court reasoned, "There can be no doubt that the benefits extended under the challenged program are as indispensable to health and well-being of illegitimate children as to those who are legitimate."

In *Jimenez v. Weinberger* [*18*] the Supreme Court held that a Social Security provision denying benefits to illegitimate children born after the onset of the insured parent's disability while allowing post-disability legitimate children to qualify for benefits constituted a denial of equal protection. *Jimenez* was decided on 19 June 1974. On 24 June 1974 the Supreme Court affirmed *Weinberger v. Beaty* [*19*], which had come up from a federal appeals court [*20*] and had been decided in accordance with the *Jimenez* decision on substantially the same issue.

The Court was unwilling to extend the equal protection and denial of due process arguments in *Mathews v. Lucas* [*21*]. In that case a provision of the Social Security Act was challenged; it required an illegitimate child to show that the deceased wage earner was the parent of the child and that the wage earner lived with or contributed to the support of the child at the time of the wage earner's death. The Court held that the statutory classification was not unconstitutional per se and was permissible because it reasonably related to the likelihood of dependency at death.

The one decision that has probably had the greatest impact on the rights of the illegitimate child is *Trimble v. Gordon* [*22*]. The Court invalidated an Illinois statute that had allowed legitimate children to inherit by intestate succession from both their mothers and fathers while illegitimate children could inherit by intestate succession only from their mothers. The court held that the statutory classification denied illegitimate children equal protection of the law and bore no rational relationship to a legitimate state purpose. The court further stated the difficulties of proving paternity did not justify a total statutory bar of illegitimate children and the fact the father could have made provisions for the illegitimate child by way of a will did not suffice to uphold the statute.

Although the court upheld the right of illegitimate children to inherit by intestate succession from both the mother and father, it also recognized the right of the state to institute formal procedures with which the child must comply to prove paternity. In *Lalli v. Lalli* [*23*] a New York statute provided that an illegitimate child could inherit from his intestate father only if a court of competent jurisdiction had entered an order declaring paternity during the lifetime of the father. The court found the statute not to be in violation of the constitutional rights of the illegitimate child, that the state had a legitimate purpose in providing for the just and orderly disposition of a decedent's property, and that the statute would assist in deterring fraudulent claims.

This series of United States Supreme Court decisions further emphasizes the need for our legal system to be more receptive to new methods of paternity testing that are capable of accurately resolving paternity disputes. In view of the rights acquired by the illegitimate child in this country since 1968, the legal profession must uniformly recognize and establish an effective procedure to determine paternity.

Blood Tests—Reliable Proof of Paternity

The results of blood tests are now recognized as the most reliable method of proving paternity [*24,25*]. In the early years the courts thought blood tests had not been proven reliable

[26] and were most reluctant to recognize the significant evidence blood tests provided [27].[3] However, the early questions of accuracy and reliability of blood tests were laid to rest in 1952, when the American Medical Association recommended without reservation that the ABO, MNSs, and Rh-Hr blood test systems be adopted for medicolegal application [28]. At present, the majority of jurisdictions have accepted the results of blood-grouping tests by judicial decision or by statute for the purpose of proving "non-paternity" [29]. However, Section 4 of the Uniform Act on Blood Tests to Determine Paternity (UBTA), enacted in 1952, permitted the use of blood test evidence to prove the possibility of paternity if the court in its discretion thought the blood factor was rare enough to be admitted into evidence as proof of paternity.

The Uniform Act on Paternity was approved by the National Conference of Commissioners on Uniform State Laws and the American Bar Association in 1960. Section 10 of the Uniform Paternity Act is essentially the same as Section 4 of the UBTA. The Uniform Parentage Act was approved by the Conference in 1973. Section 12 of the Uniform Parentage Act allows introduction into evidence of results of blood tests that show the statistical probability of the alleged father's paternity. The rules under which the results of blood tests are admitted into evidence vary from jurisdiction to jurisdiction [29].

Any constitutional challenges that may be asserted by an individual who is required by court order or state statute to submit to a blood test in a paternity proceeding would most likely be unsuccessful in view of the *Schmerber v. California* decision [30].[4] Two putative fathers advanced such an argument recently in the consolidated case of *State of Washington v. Meacham* [31]. The plaintiff-appellants attacked the constitutional validity of a court order requiring them to submit to withdrawal of blood as provided by the Uniform Parentage Act enacted by the State of Washington. The appellants asserted their rights of privacy, freedom from unreasonable search and seizure, and freedom of religion would be unduly violated if they were forced to submit to the tests. The court, citing *Schmerber v. California* [30], ruled that the intrusion was minimal and the State has a compelling and paramount interest in accurately determining the parentage of its minor children. Thus, the ability of the court or state statutes to require the concerned parties to submit to blood tests appears well established.

Today there are numerous immunologic and biochemical systems that have the potential of ascertaining paternity. In response to the need to review present-day methods of blood testing systems, the American Medical Association (AMA) and the American Bar Association (ABA) joined together to formulate some guidelines concerning serologic tests to prove paternity [32]. The Joint AMA-ABA Guidelines recommended seven basic blood group systems to be used in cases involving disputed parentage: ABO, Rh, MNSs, Kell, Duffy, Kidd, and HLA. The guideline prescribes a three-tier system for using the seven blood tests [32] (Table 1).

As a practical matter, the majority of courts still limit the introduction of blood tests to the ABO, MNSs, and Rh-Hr systems [33]. The combined probability of these systems in excluding a putative father is only 56.4% [33]. As indicated in the Joint AMA-ABA Guidelines to Serologic Testing [32], newly developed blood grouping systems utilizing the white blood cells can determine paternity at a higher rate of probability based on inheritable patterns than the blood grouping systems using the red blood cells. A short review of the various systems available follows.

[3]In the *Berry* case [27], the putative father was convicted in the paternity proceeding although the blood tests results indicated the putative father's blood type was O, the mother's A, and the child's B. It is impossible for a woman having blood type A and a man having blood type O to produce a child with blood type B.

[4]In the *Schmerber* case [30],it was held that the evidence of analysis of a blood sample taken over the plaintiff's objections was admissible into evidence and did not violate his Fifth Amendment right to be free of unreasonable searches and seizures.

TABLE 1—*Three-tier system for using seven blood tests (adapted from Ref 32).*

Blood Group System	Mean Probability of Excluding Paternity		
	Black	White	Japanese
	LEVEL I		
ABO	0.1774	0.1342	0.1917
Rh	0.1859	0.2746	0.2050
MNSs	0.3206	0.3095	0.2531
	LEVEL II[a]		
Kell	0.0049	0.0354	0
Duffy	0.0420	0.1844	0.1159
Kidd	0.1545	0.1869	0.1573
	LEVEL III[b]		
HLA	0.78 to 0.80	0.78 to 0.80	0.78 to 0.80

[a]Increases mean probability of exclusion from 63 to 72%; to be performed when Level I tests do not allow exclusion.

[b]Increases mean probability of exclusion to at least 90%; to be performed when Level II tests do not allow exclusion.

ABO Blood Group

The ABO blood groups were discovered by Landsteiner in 1901 revealing, for the first time, the existence of intraspecies differences in human blood [*34*]. Soon it was shown that such differences are genetically inherited and are transmitted unchanged from generation to generation [*35*]. By determining the ABO blood type of members of a family one can establish in a percentage of cases whether an offspring is not the product of a mating between the mother and the male partner. As an example, a mating between a Group O mother and a Group A father may produce a Group O or a Group A offspring, but not a Group B [*36*].

The ABO group is genetically transmitted by a series of co-dominant allelic genes that occur on one locus on a pair of chromosomes. The A, B, and O represent the major alleles in the system. An allele is one of two or more alternative genes that may be present at a given locus in a chromosome. The genes induce the comparable antigen to be formed on the red cell membrane. An antigen is a substance that will stimulate the production of antibodies and react with them. The O gene is amorphic and does not lead to the transformation of a precursor substance into a new antigen.

To determine an individual's blood type according to the ABO system, anti-A and anti-B sera are reacted with the red cells of the individual's blood sample. Agglutination (clumping) occurs when the red cells carry the corresponding antigen or antigens. The results are confirmed by testing the serum with known A and B cells to determine the antibody or antibodies present in the serum. Antibodies are proteins synthesized by the human or animal body in response to antigens. The acquired information allows the individual to be classified into one of the four major blood group phenotypes: O, A, B, or AB [*36*]. The phenotype is the observable characteristic of an individual as determined by his genes.

The antigens of the ABO blood group system are well developed on the red cell even before birth [*37*]. The calculated probability of excluding a putative father using the ABO system is 17.6% [*38*].

MNSs Blood Group

In searching for antibodies other than those found in the ABO system that would distinguish between human bloods, Landsteiner and Levine [*39*] injected rabbits with human

red blood cells. As a result the rabbits developed two different antibodies—anti-M and anti-N. Using the sera of the immunized rabbits as reagents they were able to divide human blood into the M, N, and MN phenotypes [*36*].

In 1947, Walsh and Montgomery [*40*] found an unusual antibody in the serum of a woman who had recently given birth to a child suffering from hemolytic disease of the newborn. The antibody appeared to be detecting an unrecognized blood group tentatively called S. Sanger and Race [*41*] demonstrated that the antigen S was genetically associated with the MN blood groups. In 1957, Levine et al [*42*] discovered the anti-S antibody and showed it reacted with the product of an allele to S. In 1958, Allen et al [*43*] reported a new antigen, M^g, an allele at the MN locus. The M^g blood factor has a very low frequency in the population (1 in 44 000) [*44*].

The M, M^g, N, and Ss antigens are well developed in the newborn and remain unchanged throughout life [*36*]. The MNSs system provides a very significant, efficient blood test for ascertaining paternity because the genes in this system in the various populations allows a higher percentage of distinction among randomly selected individuals [*45*]. The calculated probability of excluding a putative father using the MNSs system alone is 31.6% [*36*].

Rh-Hr Blood Group

In 1940 Landsteiner and Wiener [*46*] recognized a new antigen as a result of an antiserum produced in a rabbit following the injection of the blood of the Rhesus monkey. The new antisera cross-reacted with human M antigen. The antigen was called Rh and found to react with approximately 85% of the white population. By contrast, 93% of blacks are Rh positive and 99% of Orientals are Rh positive. The cells agglutinated by the new antisera were termed Rho-positive and those which gave negative results were called Rho-negative [*37*]. Later rh′ (present in 70% of whites) and rh″ (present in 30% of whites) were discovered [*36*]. Levine [*47*] found a new antibody, anti-hr′, which recognized the allele of the rh′ antigen. Soon thereafter the allele of rh″ was found and named hr″ to correspond to the rh′-hr′ relationship [*48*].

Later two principal competing theories and nomenclatures were developed and advanced to explain the complexities involved in the Rh-Hr blood group system. The Wiener concept [*49*] postulated that the Rh locus on the chromosome was the site of many allelic genes and this gene was transmitted from generation to generation as a single nondivisible unit. The gene determined an agglutinogen recognized by many blood factors, each of which was specifically identifiable by a corresponding antibody [*36*]. The Fisher-Race concept [*50*] postulated that three pairs of genes occupied three separate and distinct, yet closely linked, loci on each of a pair of chromosomes. The three genes were designated D for Rho, C for rh′, and E for rh″. There was an implied possibility that crossing-over could take place or that the separate elements of the CDE unit could be transmitted. The Committee on Medicolegal Problems of the American Medical Association adopted the Wiener Rh-Hr nomenclature because it assisted in a better understanding of the complicated system [*36*].

The Rh-Hr blood group system is extremely complex and highly sophisticated. To use the test properly, the technician must have a sound understanding of basic genetics, familiarity with the variants, and knowledge of the techniques necessary for demonstration [*51*]. The calculated probability of excluding a putative father using the Rh-Hr system alone is 25.0% [*36*].

Kell Blood Group

The Kell blood group system was discovered in 1946, when the red cells of an infant suspected of suffering from hemolytic disease of the newborn gave a positive direct antiglobulin test. The reaction indicated the red cells were coated with an antibody. When the reaction

could not be explained with the Rh incompatibility theory, the mother's (Mrs. Kell's) serum was investigated and an antibody was discovered that reacted with the cells of her husband, an older child, and the afflicted child [*52*]. As a result of the findings a new blood group antigen was found and termed Kell (K).

Although other antigens related to the Kell system have been discovered, the most useful antigens in paternity testing are the k, an allele of K discovered by Levine et al [*53*], and the Js^a [*36*]. The antigen Js^a is useful only in paternity testing of blacks because it occurs in approximately 19.0% of blacks, it is present in less than 0.05% of whites. The calculated probability of excluding a putative father through the Kell system alone, with the K, k, and Kk phenotypes, is 3.8% [*36*].

Duffy Blood Group

In 1950, Cutbush et al [*54*] described a new blood system after finding a new antibody in the serum of a hemophiliac. The antibody was immune in nature, resulting from transfusions he had previously received. The antibody was called anti-Fy^a. The discovery of a reciprocally related antibody called anti-Fy^b [*55*] established a new system called the Duffy blood group system, controlled in whites by two co-dominant genes, Fy^a and Fy^b. In blacks the predominant phenotype is $Fy^{(a-b-)}$, indicating the majority of blacks (68%) lack both genes [*36*]. The phenotype $Fy^{(a-b-)}$ is extremely rare among whites. The calculated probability of excluding a putative father using the Duffy system alone is 7.0% [*36*].

Kidd Blood Group

Allen et al [*56*] found an antibody in the serum of a mother whose child had hemolytic disease of the newborn. The newly found antigen was named Jk^a and was present in about 75% of whites [*36*]. In 1953, anti-Jk^b was discovered [*57*]. The calculated probability of excluding a putative father using the Kidd system alone is 6.0% [*36*].

HLA Blood Group

The HLA system of tissue typing is extremely powerful in determining the probability of paternity [*58*]. Unlike the six blood group systems discussed previously whose systems revolve around antigens occurring on the red blood cells (erythrocytes), the HLA system is based on antigens found on the white blood cells (leukocytes). Leukocyte antibodies were first observed in 1953 [*59*]. In the late 1960s HLA testing was being used for defining donor-recipient compatibility in organ transplant programs [*60*]. HLA typing is now recognized throughout the world as the single most discriminating test in excluding paternity [*61*]. The basic principle underlying HLA is the antigen produced by genes and found in the white blood cells. The A and B loci of the HLA region are used in the HLA procedure to determine paternity. An individual has two alleles or two genetic expressions for antigens. The allele represents an alternative form of a gene occupying the same locus on paired chromosomes [*62*].

The summary of identifiable antigens at the cell surface is an individual's phenotype. The basis for the phenotype is derived from inheritance patterns, called the genotype, among the offspring of a family. The genotype is the assemblage of genes found in the chromosomes of an individual. The haplotype comprises one A locus allele and one B locus allele on the same chromosome. Each inherited chromosomal region composed of four genes is termed a haplotype. The combination of the A and B loci alleles are transmitted between generations as a packet. Two haplotypes, one from each parent, constitute the genotype of each person. Thus, when the A and B regions of a chromosome are examined, the maximum number of HLA antigens to be found on a cell is four. In the event the number of antigens is less than four there are only two possible explanations: (1) at a given locus the individual is homozy-

gous, meaning he has identical alleles at the particular locus on the paired chromosomes (for example, A2, A2) or (2) the individual possesses an antigen that cannot be detected with antisera presently available. However, the incidence of undetectable antigens at the A and B loci is less than 2% [*63*].

Figure 1 illustrates the basic principles used in the HLA system. The mother and child both have the A1-B8 haplotype. The child could have inherited the A1-B8 haplotype only from his mother because the same haplotype is not found in putative Father A or putative

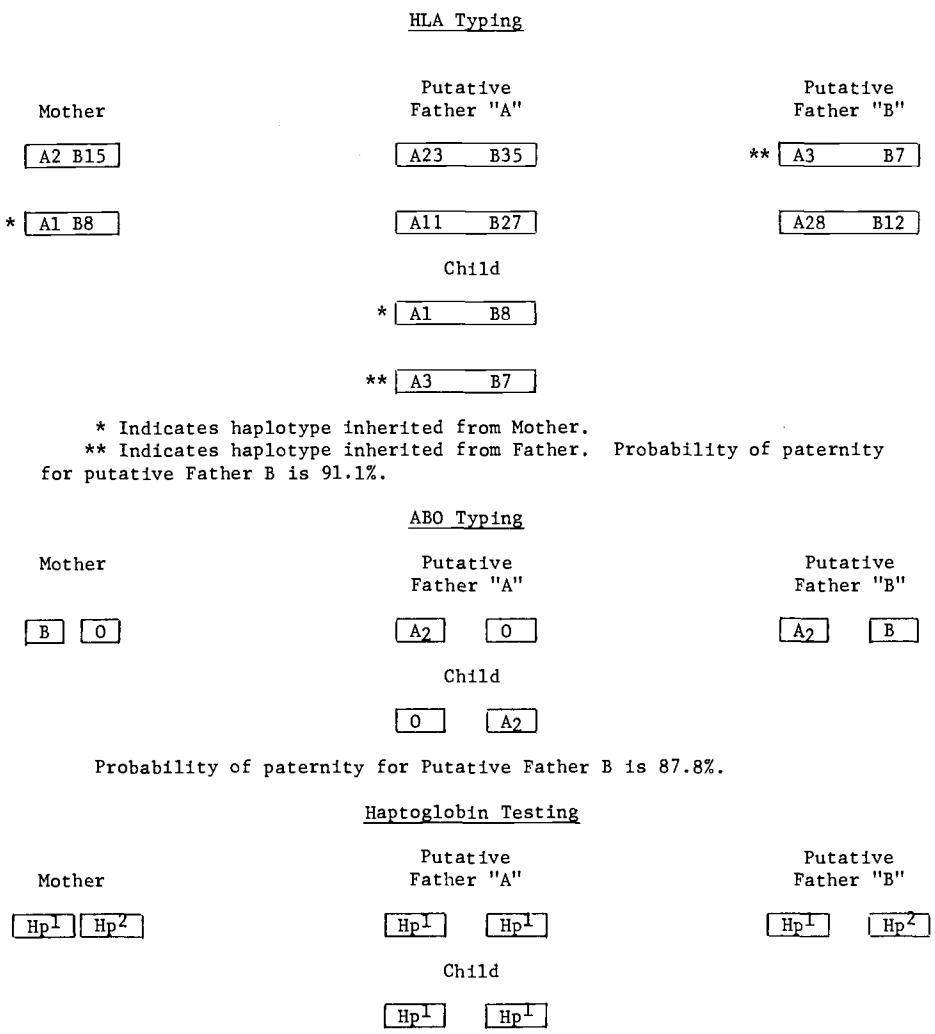

FIG. 1—*Illustration of three independent genetic systems for ascertaining paternity. An individual has one pair of chromosomes for determining HLA, one pair for ABO, and one pair for haptoglobins. The child inherited chromosomes for (1) HLA-A1-B8, (2) Type O, and (3) Hp^1 from its mother and (1) HLA-A3-B7, (2) Type A_2, and (3) Hp^1 from the father. Note that although putative Father A possessed two of the required chromosomes (A_2 and HP^1) he is excluded because he does not have the HLA groups A3 and B7. Putative Father B possessed all the required chromosomes necessary to be the actual father of the child and cannot be excluded (adapted from Ref* 63*).*

Father B. No human leukocyte antigen could be present in a child if they do not exist in either parent. Therefore, the remaining group must come from the father. Putative Father B has the A3-B7 haplotype and cannot be excluded as the child's father. Putative Father A is automatically excluded because he lacks the A3-B7 haplotype.

Although putative Father B in Fig. 1 cannot be conclusively confirmed as the father of the child based on the results of HLA testing, formulas have been established to calculate the mathematical probability of his actually being the child's father [*64*]. First, the probability of paternity for a nonexcluded putative father is calculated by computing the chance that the putative father in a mating with the mother would produce a child of the required phenotype. All possible combinations for persons of their phenotypes are considered in the computation. This probability result for the putative father is then compared to the chance of a random male in a mating with the mother producing a child of the same phenotype. The random possibility is computed by using the population frequencies of the genotypes [*63*]. It should be noted that only 1 in 1000 randomly selected individuals will have a similar HLA type [*58*]. The probability of paternity based on the results of HLA testing for the example in Fig. 1 is 91.1%. However, by employing several serological testing procedures a higher level of probability can be attained that would merit a positive assignment of paternity. Thus, when the probability percentages of the HLA, ABO, and haptoglobins results are combined, we obtained an overall probability of 99.0% [*63*].

In an extensive study of 1000 paternity cases conducted by Terasaki,[5] a foremost authority on HLA, it was possible to achieve in most instances 90% or greater probability of paternity in nonexclusion cases by using HLA typing as the basic test. When the ABO and haptoglobin blood typing tests were added to the HLA test, the nonexcluded putative father usually had more than a 95% probability of paternity. Eighty-five percent had more than 95% probability and 22 out of 53 nonexcluded cases had a 99% probability of paternity. In cases where the putative father was excluded there was no question, since it is impossible for an excluded male to be the biological father of a child based on genetics [*63*].

The most astounding case in which the efficacy of HLA typing in paternity determinations was demonstrated involved a set of twins. Initially the mother, the putative father, and the twins were tested by HLA typing. The results indicated that the putative father could not be excluded as the father of Twin 1 and the probability of paternity for that twin was 96.8%. However, based on his HLA phenotype he was definitely excluded as the father of Twin 2 (Fig. 2). The mother was then asked about the possibility of another man. She named another possible father who also submitted to HLA typing. From Fig. 2 it is clear that Putative Father 2 could not be excluded as to Twin 2. Putative Father 2 possessed the required paternal haplotype for Twin 2 with a probability of paternity of 99.9% [*65*].

The medical community has recognized the power of a polymorphic genetic system to provide evidence of exclusion of a putative father and evidence to support a finding of paternity when a man is in fact the father of an illegitimate child [*66*]. The HLA system is extremely polymorphic; there are many different antigens presently recognized as part of the system (Table 2). It reaches full expression prior to birth, and it appears not to be disturbed by environmental conditions such as massive blood transfusions, drugs, or disease [*62*].

Admissibility of HLA in Paternity Proceedings

As stated earlier in this article, it is generally held by statute or court decision that the results of blood grouping tests may be admitted into evidence only to prove nonpaternity [*68*]. The courts generally recognize that the results of blood tests establishing nonpaternity are conclusive on the issue unless the jury is presented evidence that the testing procedure was not performed accurately [*68*]. It is argued that if courts admit evidence that proves the

[5]Paul I. Terasaki, Ph.D., University of California at Los Angeles, unpublished data.

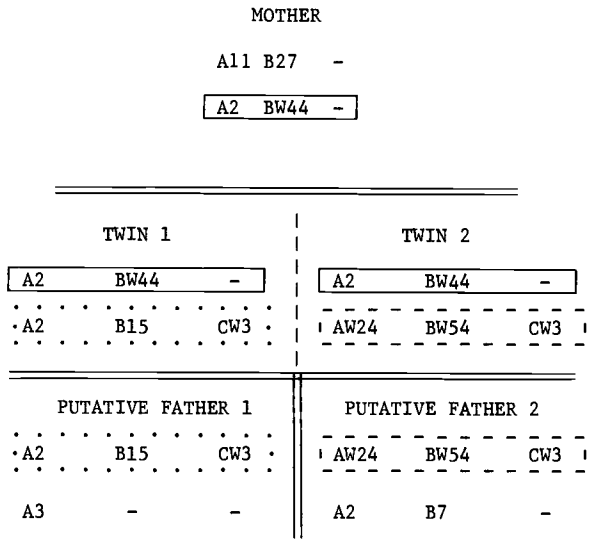

FIG. 2—*The HLA genotype of the mother can be deduced from the antigens in common between the mother and the twins (solid lines). The antigens with the dotted lines must have been inherited by Twin 1 from the father and are present in putative Father 1. Similarly, antigens of Twin 2 (dashed lines) are the paternal antigens present in putative Father 2. Mutual exclusion of the fathers is apparent. The* (-) *in the genotype indicates an unknown antigen, homozygosity, or a true amorphism. Reprinted with permission from Ref* 65.

possibility of paternity based on the percentage of probability the evidence would be unduly prejudicial [*69*]. Jaffee [*70*] asserted this argument in a recent article. He vehemently argued against the use of "probabilistic or statistical evidence as direct, independent, primary proof upon an issue of affirmative, ultimate, actual (existential or parametric) fact with respect to which the party has the burden of persuasion." He contended that HLA results can never directly support an assertion of knowledge that the alleged party is in fact the father and that such scientific evidence may appear compelling to a jury and thus unduly prejudicial.

Paternity proceedings are essentially recognized as civil actions [*24,71*]. In civil actions the degree of proof required is by a preponderance of the evidence, not absolute fact [*72*]. The burden of proving the facts alleged in the pleadings and persuading the jury is placed on the plaintiff. Beyond testimony of the parties and witnesses, the single most reliable proof plaintiff would have to present is the blood test. The great majority of courts admit the results of blood tests as evidence to establish nonpaternity [*29*]. It is contended that when the blood test results do not exclude paternity, the results still should be admitted into evidence and the degree of probability should go to the weight of the evidence [*73*]. The quest is for truth. When the validity of a conclusion depends on another discipline and the application of that discipline will yield a more rational decision than traditional legal rules, the rules applied to the solution of legal disputes must be reformulated if they are to be considered just.

To continue to adhere to the rule of admitting blood tests results into evidence only when they prove nonpaternity affords the putative father every advantage and works an inequity against the mother. The putative father has nothing to lose by submitting to any blood test procedures, for the rule protects him by admitting the evidence when the results indicate exclusion and prohibits the results from coming into evidence if the tests do not exclude him. Now that blood grouping techniques have become more sophisticated, the results of these tests should at least be admitted as circumstantial evidence of paternity [*74*]. To continue to

TABLE 2—*Complete listing of recognized HLA specificities as of July 1980.*[a]

HLA-A	HLA-B	HLA-C	HLA-D	HLA-DR
HLA-A1	HLA-B5	HLA-Cw1	HLA-Dw1	HLA-DR1
HLA-A2	HLA-B7	HLA-Cw2	HLA-Dw2	HLA-DR2
HLA-A3	HLA-B8	HLA-Cw3	HLA-Dw3	HLA-DR3
HLA-A9	HLA-B12	HLA-Cw4	HLA-Dw4	HLA-DR4
HLA-A10	HLA-B13	HLA-Cw5	HLA-Dw5	HLA-DR5
HLA-A11	HLA-B14	HLA-Cw6	HLA-Dw6	HLA-DRw6
HLA-Aw19	HLA-B15	HLA-Cw7	HLA-Dw7	HLA-DR7
HLA-Aw23 (9)	HLA-Bw16	HLA-Cw8	HLA-Dw8	HLA-DRw8
HLA-Aw24 (9)	HLA-B17		HLA-Dw9	HLA-DRw9
HLA-A25 (10)	HLA-B18		HLA-Dw10	HLA-DRw10
HLA-A26 (10)	HLA-Bw21		HLA-Dw11	
HLA-A28	HLA-Bw22		HLA-Dw12	
HLA-A29	HLA-B27			
HLA-Aw30	HLA-Bw35			
HLA-Aw31	HLA-B37			
HLA-Aw32	HLA-Bw38 (w16)			
HLA-Aw33	HLA-Bw39 (w16)			
HLA-Aw34	HLA-B40			
HLA-Aw36	HLA-Bw41			
HLA-Aw43	HLA-Bw42			
	HLA-Bw44 (12)			
	HLA-Bw45 (12)			
	HLA-Bw46			
	HLA-Bw47			
	HLA-Bw48			
	HLA-Bw49 (w21)			
	HLA-Bw50 (w21)			
	HLA-Bw51 (5)			
	HLA-Bw52 (5)			
	HLA-Bw53			
	HLA-Bw54 (w22)			
	HLA-Bw55 (w22)			
	HLA-Bw56 (w22)			
	HLA-Bw57 (17)			
	HLA-Bw58 (17)			
	HLA-Bw59			
	HLA-Bw60 (40)			
	HLA-Bw61 (40)			
	HLA-Bw62 (15)			
	HLA-Bw63 (15)			

The following specificities are generally agreed to be included in Bw4 and Bw6.

Bw4: B13, B27, B37, Bw38 (w16), Bw44 (12), Bw47, Bw49 (w21), Bw51 (5), Bw52 (5), Bw53, Bw57 (17), Bw58 (17), Bw59, Bw63 (15)

Bw6: B7, B8, B14, B18, Bw35, Bw39 (w16), Bw41, Bw42, Bw45 (12), Bw46, Bw48, Bw50 (w21), Bw54 (w22), Bw55 (w22), Bw56 (w22), Bw60 (40), Bw61 (40), Bw62 (15)

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exclude the results of these newly developed blood tests that have demonstrated their accuracy and reliability under the auspices of undue prejudice to the putative father is a gross miscarriage of justice.

Jaffee [*70*] refers to *People v. Collins* [*75*], emphasizing the court's rejection of testimony of a mathematician who stated the probability of other persons committing a robbery with which the defendant couple (a man and woman with special characteristics) had been charged. The court held that the compelling scientific form attributed undue weight to the evidence, making it unduly prejudicial. Jaffee goes on to say that "might-be's" were immaterial. The issue was either were the defendants actually the culprits or did the defendants in fact com-

mit the act. He then reasons the evidence did no more than prove the defendants were possible suspects. Thus, Jaffee concludes the evidence was irrelevant, as would be the probability of paternity as shown by HLA. However, the court also stated in its opinion it discerned no inherent incompatibility between the disciplines of law and mathematics and intended no general disparagement of the latter as an *auxiliary* in the fact-finding processes of the former. The court objected to the results of the mathematician being admitted without adequate evidentiary foundation and with inadequate proof of statistical independence. It was the technique employed in the *Collins* case [*75*] that led the court to reverse the conviction of the defendants and proclaim the admission of the probability results to be prejudicial error.[6]

Any evidence is relevant if it logically tends to prove or disprove any material fact at issue in the case, and every act or circumstance serving to elucidate or put light upon a material issue or issues is relevant. Therefore, relevancy is established when the fact offered tends to prove a fact in controversy or renders the matter at issue more or less probable [*72*]. This is precisely the position taken by the Supreme Court of North Dakota in *North Dakota v. Unterseher* [*76*]. The defendant, adjudged to be the father of an infant child by a district court, appealed, alleging among other things that the results of nonexclusionary blood-grouping tests were improperly admitted into evidence. The court stated [*76*], in no uncertain terms,

> The report of nonexclusionary blood-groupings is of probative value for the determination of the ultimate issue in a paternity action—whether the defendant is the father of the illegitimate child—in that it rebuts the negative proposition that Unterseher cannot be the father of Sharon Olson's infant child.... The report of nonexclusionary blood-groupings is just as relevant as is the color of a child's hair or the color of a child's eyes, evidence that has been traditionally received to aid in the establishment of paternity.

The Supreme Court of Minnesota recently rendered several decisions suggesting to the legislature the accurate adjudication of paternity proceedings could significantly be enhanced by providing for the availability and utilization of current blood-grouping tests [*77–79*]. The Court included in their decisions the recommendations of the joint report of the AMA and the ABA [*32*] endorsing the use of a series of seven tests to be performed in paternity proceedings that could raise the probability of exclusion from 91 to 93%. The court concluded that the results of blood tests in combination with statistical studies may have probative value in affirmatively establishing paternity in addition to the traditional value of proving nonpaternity [*78*].

In a 1978 decision in *Michael B. v. Superior Court of Stanislaus County* [*80*], a California Appellate Court, Fifth District, upheld a lower court's decision requiring the county to pay the cost of a HLA blood test for an indigent involved in a civil paternity suit. The court also held as a matter of law that even when the results of blood tests do not exclude the putative father, it could be a significant factor to be considered by the parties in resolving paternity cases, particularly where there is limited evidence on the paternity issue and in view of the fact the HLA test was helpful in determining statistical probabilities of paternity.

The most provocative decision advocating the merits of the HLA test as proof of paternity was decided by a California Appellate Court, Fourth District, in the case of *Cramer v. Morrison* [*81*]. The central issue of the case was whether or not the results of the HLA test were admissible to establish the probability of paternity. The defendant advanced the argument that (1) California law precluded the use of blood test results to prove paternity and (2) the results based on probabilities produced a prejudicial effect of the evidence, outweighing its probative value.

The HLA test, conducted by Dr. Terasaki, indicated that there was a 98.3% probability that the defendant was the father of the child. The court held that apart from the possibility of exclusion of the HLA test by statute, and assuming its acceptance in the scientific community as a reliable test for paternity, the results of the test were clearly probative and rele-

[6]In the *Collins* case [*75*], the mathematician testified that the probability of another couple other than the defendants committing the crime was 1 out of 12 000 000.

vant in an action to establish paternity. The court also stated that when the California legislature adopted the Uniform Act on Blood Tests to Determine Paternity in 1953, including the provision of the model act that permitted the use of results of blood tests as conclusive evidence of nonpaternity and omitting the part that would have allowed the results of blood tests to show the possibility of paternity, the drafters did not have in mind tests of the nature of HLA. In reviewing the legislative history of California the court found the blood tests referred to by the statute were the red cell blood grouping tests (ABO, MN, and Rh-Hr). The court pointed out the HLA test involved tissue typing of the white blood cells and yielded higher probabilities of paternity than the standard red cell blood grouping tests. The HLA test was not even in existence when the legislature enacted the Act [*81*].

The court referred to the California Supreme Court decision in *People v. Collins* [*75*], noting that in *Collins* interpretations were based on arbitrarily assigned numerical probability values or on a statistical theory unsupported by evidence. The court distinguished *Collins* from HLA test interpretations, noting that HLA results are based on objectively ascertainable data and a statistical theory based on scientific research and experiment. The court also stated there is a probability factor in the most carefully constructed scientific venture; however, it is impossible to exclude all chance of error in any human endeavor. The court concluded the law did not require that the admissibility of scientific test evidence be predicted on a 100% degree of accuracy, and thus HLA test results were admissible to prove paternity assuming a preliminary showing of general acceptance of the new technique in the relevant scientific community [*81*].

In *County of Fresno v. Superior Court of Fresno County* [*82*], a later California Appellate Court Fifth District decision, petitioners challenged a trial court's decision denying a motion for a HLA test to establish parentage in a civil paternity suit when extended blood factor testing had previously been performed and the test failed to exclude the defendant. The appellate court granted the petitioners' motion, ordering all parties to submit blood samples for HLA analysis and stating, "The very existence of another more sophisticated and exact test is sufficient 'good cause' in and of itself to warrant use of the second test by the court in successfully completing the difficult search for truth." The court added public policy favored the use of objective, highly accurate scientific analysis, the HLA test afforded highly probative evidence on the issue of paternity, and the state owed to the child an assurance that an accurate determination of parentage would be made [*82*].

On the other hand, in *Simons v. Jorg* [*83*] a Florida Appellate Court, Second District, quashed a lower court's order requiring the petitioner to submit to HLA blood testing to determine paternity. The court held that discovery was permissible only on matters reasonably calculated to lead to admissible evidence and there was nothing in the record indicating that the HLA test results would be admissible or even lead to admissible evidence. The Florida Department of Health and Rehabilitative Services filed a motion for leave to appear as amicus curiae for the purpose of filing a motion for rehearing on the issue of using HLA testing in disputed paternity proceedings. The department brought to the court's attention the fact that the HLA typing test could accurately determine the probability of paternity. In denying the motion the court acknowledged the department's statements as to the admissibility of evidence of blood tests reflected the current law applicable to the traditional blood grouping tests but thought the relevancy of HLA as evidence to prove paternity was not an issue to be decided in that late stage of the certiorari proceedings.

The case was brought before the Florida Appellate Court again in June 1980 [*84*]. At the lower court level the respondent filed another motion compelling the petitioner to submit to HLA testing. A pathologist had testified at the trial that the HLA test was not in general use to prove paternity but was a more sophisticated procedure whose results yielded probabilities of paternity far higher than those of any of the traditional blood grouping test. The Appellate Court then found the respondent had shown good cause to compel the petitioner to submit to the blood test, based on the undisputed evidence that the HLA blood test was reliable and accurate. However, the court cautioned it had not decided the question of the

admissibility of HLA test results as evidence at trial, nor could it anticipate what weight the trier of fact would give such medical evidence, if admissible, together with other evidence offered in determining the issue of paternity.

In August 1980 the Florida Appellate Court decided the question of admissibility of HLA results for the purpose of establishing paternity in the case of *Carlyon v. Weeks* [*85*]. In the paternity proceeding brought by the mother of an illegitimate child against the putative father, the trial court admitted into evidence the results of the HLA blood test performed on the parties. The trial court found the reliability and validity of the HLA test results were sufficient and of probative value on the issue of establishing paternity. The Florida Appellate Court agreed with the trial court's rationale, stating the decision to allow the HLA results into evidence was within the trial court's discretion.

In October 1980 a putative father appealed to the Florida Appellate Court after the trial court rendered a final judgment of paternity against him. The father argued the trial court erred in admitting the results of the HLA test and allowing the results to be used as the primary means of proving paternity in the case of *McQueen v. Stratton* [*86*]. In affirming the judgment of the trial court, the Florida Appellate Court held a putative father could be compelled to submit to HLA testing once the mother showed good cause and the results of the test would be admissible.

In the Massachusetts case of *Commonwealth v. Blazo* [*87*] a putative father who was judged to be the father of an illegitimate child requested the court to order the child and mother to submit to HLA tests. The trial court denied the motion. The Appeals Court of Massachusetts affirmed the trial court's decision. However, the appellate court took judicial notice of the high degree of accuracy attained from HLA tests and the recent recognition HLA tests had received from the scientific and medical community. The court cautioned that in future cases, should the putative father request HLA tests be performed, the trial judge should carefully consider, in the exercise of his or her judgment, ordering the administration of the HLA test to the defendant, mother, and child.

In *Malvasi v. Malvasi* [*88*] a New Jersey Superior Court had to decide on the use of the HLA test as an aid in establishing paternity. The putative-father-husband had made a motion compelling the mother-wife to submit to the test. In granting the motion the court held based on the scientific community's recognition of the reliability and accuracy of the HLA test and its important probative value where paternity is an issue a court has to consider such medical evidence in addition to other proofs in deciding parentage. The court also stated that by using the HLA system the probability of a nonexcluded male being the actual father was usually over 90%, and thus its results could be used as affirmative evidence to show parentage.

In a later decision, *M. v. S.* [*89*], a New Jersey Superior Court held blood grouping tests and the related expenses were necessary for a proper defense in a paternity proceeding and affirmed a lower court's order that an indigent be given the test at public expense. In announcing its opinion the court stated HLA testing represented the state of art in blood testing in ascertaining paternity.

In the case of *Commissioner of Social Services of Onondga County v. Lardeo* [*90*], the respondent putative father filed a petition to have the Department of Social Services pay for an HLA test after the tests of the ABO, MNSs, the Kell, the Duffy, and the Rh-Hr blood grouping systems paid for by the county failed to exclude him. The court held to exclude those who were financially unable to afford a blood test from benefits of such a powerful test as the HLA test in a paternity proceeding was an affront to notions of equity if not a blatant barrier to due process of law. The court further stated that blood tests provided protection for both the public and the alleged father and the HLA system made it possible to increase that protection from approximately 60% to approximately 90%. The county was required to pay for the costs of the HLA test.

In the later New York case of *Goodrich v. Norman* [*91*] the court would not go so far as to allow the results of an HLA test into evidence to prove paternity despite the fact the HLA test

had been proven to be the most comprehensive test to be used in ascertaining paternity. In this unusual case the putative father filed a petition asking the court to adjudicate the paternity of an illegitimate child. The child had been placed in a foster home after the mother had been rendered incapable of caring for it because of emotional problems. The putative father told the court he did not know whether or not he was the father of the child, but if he was found to be the father he was willing to accept his responsibilities. The court was then requested to order blood tests including the HLA test. The ABO system did not exclude the putative father and the MNSs system made an indirect exclusion. However, further testing indicated the child had three antigens in the HLA system and one antigen in the Rh-Hr system that were not present in either the mother or the putative father. The results definitely excluded the alleged father.

Although the outcome of the blood tests made it unnecessary for the court to confront the issue of whether or not HLA test results would be admissible to prove paternity, the court stated the present New York law and state statute prohibited the use of such results to prove paternity, despite the fact that probative value of the HLA test outweighed the prejudicial effect. The court did voice its concern that the state statute[7] as written might be in violation of due process of law and urged the legislature to re-examine the statute [*91*].

The Supreme Court of Utah affirmed a lower court's decision refusing to grant appellant a writ of habeas corpus in the case of *Marticorena v. Miller* [*92*]. The matter involved two men, each claiming to be the biological father of a child. The appellant, who had received an adverse ruling on the paternity issue in a prior litigation, sought to raise the issue again based on the new blood grouping system of HLA. The court refused the appellant's request saying the issue could not be raised a second time. However, the dissenting opinion noted that at the time of the original hearing the blood tests used could not exclude either party and the HLA test was not available. Based on the accuracy of the HLA test the dissent would have remanded the case for analysis of new evidence.

The State of Utah adopted the Uniform Paternity Act, which specifically allows the results of blood tests to be used to show the probability of paternity. In *Phillips v. Jackson* [*93*] the state Supreme Court was faced with the question of whether or not the HLA test had met the prerequisite legal standards established for admission of scientific evidence new to the courtroom. In its opinion the court conceded the fact that the results of HLA testing were admissible into evidence to prove the probability of paternity if the test was proven to meet the necessary foundational requirements for admission of scientific evidence. The court then devoted the remainder of the opinion discussing the legal standards that determined the admissibility of scientific evidence new to the courtroom.

The court stated the most widely used standard for making such determinations was formulated in *Frye v. United States* [*94*]. The court noted the verification of a basic principle and its application through widespread replication and practical usage was an appropriate indication of reliability. In citing to three federal decisions [*95–97*] the court made it clear that the *Frye* standard did not demand infallibility as a condition of admitting scientific evidence. The court cautioned general acceptance should not be applied too restrictively, noting the *Frye* standard has been criticized as too rigorous [*93*]. As a result, some jurisdictions have held that conflicting expert opinion affects only the weight of the evidence and not the admissibility of it, thereby modifying the rule according to *Frye* [*98*]. The court then reasoned the paramount concern is that the evidence is sufficiently reliable. The decision formulated a list of elements that must be addressed to establish a sufficient foundation for the admissibility of HLA [*93*]:

> (1) the correctness of the genetic principles underlying the test for determining paternity; (2) the accuracy and reliability of the methods utilized in application of the principle to determine paternity; (3) the effect of variables such as occur in persons of different nationalities or ethnic

[7]Section 532 of the Family Court Act of New York clearly states the results of blood tests may only be received into evidence where definite exclusion of the putative father is established.

origins that would influence the accuracy of the test; (4) other factors that might tend to invalidate the test or significantly change the probability of accuracy; (5) establishing that the actual method employed and the particular test used in a given case were performed in accordance with proper procedures and with proper materials and equipment; and (6) the qualifications of the necessary witnesses.

The court noted that published articles and books may be used as evidence supporting Elements (1) and (2) [*93*]. The court also made it clear it was aware of the various medical and legal literature asserting the accuracy of the HLA test and its wide acceptance.

In *J. B. v. A. F.* [*99*] a Wisconsin appellate court carefully reviewed the merits of the HLA test as presented in various literature sources but concluded the results of the HLA test could not be admissible under Wisconsin's highly restrictive statutory approach to the use of medical evidence in paternity disputes. However, the court suggested that in view of the medical advances and changed social conditions that have occurred, the limiting nature of the statute should be reviewed.

Federal Requirements—Paternity Determinations

In view of the fact a great number of illegitimate children are recipients of benefits under Aid to Families with Dependent Children programs, the federal law requires that a state plan for aid and services to needy families with children must include a provision compelling each applicant or recipient to cooperate with the state in establishing paternity of an illegitimate child who is claiming aid under the program as a condition of eligibility [*100*]. Another federal statute [*101*] further provides that the state plan for child support must include a provision whereby the state will undertake to determine paternity of an illegitimate child claiming benefits. As an incentive to encourage states to ascertain paternity, the federal government has enacted a statute appropriating funds to be used for that specific purpose [*102*]. As a result of that enactment, a study was conducted to determine the effectiveness of blood test procedures and the number of state and local laboratories capable and willing to perform blood tests to establish paternity [*103*]. The relative recommendations and conclusions of that study were (1) state laws should be changed to allow introduction of blood test evidence by deposition rather than by expert testimony alone, (2) the states should adopt provisions for accepting blood test evidence for establishing probability of paternity as well as probability of nonpaternity, and (3) the study endorsed the recommendations of the AMA and ABA [*32*], adding that when an exclusion is not produced with the ABO, Rh-Hr, MNSs, Kell, Duffy, and Kidd systems, HLA testing should be done to bring the probability of exclusion to the 90% level [*103*].

Conclusion

The HLA test, performed in conjunction with other blood tests as recommended by the AMA and ABA [*32*], has demonstrated its ability to raise the mean probability of excluding a putative father to at least the 90% level. As the percentage of exclusion approaches 100% with the HLA test, so the scientific ability to calculate the likelihood of an alleged father being the actual father increases. The question of paternity must be dealt with empirically. Our legal system must be more receptive to the reliability of the HLA test results and allow them into evidence. Where the test results indicate the possibility of an alleged father's paternity, the degree of probability should be allowed into evidence and considered along with other traditional evidence. When the test results exclude a puntative father, the results should operate as conclusive evidence of nonpaternity. The legal profession's use of such vital scientific evidence in litigating paternity disputes would lend the proceeding much more credibility and reliability and provide a more efficient method of reaching the truth.

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