JURIMETRICS AND THE ASCERTAINMENT OF PATERNITY

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The aim of the present essay is to shed light on the possibilities of jurimetrics from the points of view just referred to and to do so against the background of some jurimetrical investigations in the area of paternity ascertainment.

The blood group statistical index (the paternity index) is of great importance for the assessment of probability in paternity suits in Sweden. On the basis of this index, and with the aid of Bayes's theorem, it is possible to assess the (*a posteriori*) paternity probability of the named man.[6] The *a posteriori* paternity probability with reference to the magnitude of the paternity index—a figure which is passed on to the court in the expert opinion submitted to it—is calculated on the basis of an *a priori* paternity probability of 0.50 (50 %). In one of my studies below an attempt is made to develop a modified method for assessing the paternity probability with reference to the paternity index by not postulating the *a priori* probability at 0.50 but by fixing it instead at a more realistic figure (section III). In another study an empirical and jurimetrical investigation is made as to the value of information about the length of pregnancy in ascertaining paternity (section IV). I then present and apply a jurimetrical method whereby the efficiency of the administration of justice in the sphere in question can be checked. This method makes it possible to calculate in how many instances out of a particular sample of paternity cases the paternity claim ought to have been dismissed (section V). Finally, I describe some instances of quantitative analysis of cases decided within the field in question (section VI). Since the reader cannot be expected to be familiar with the Swedish law on the ascertainment of paternity, a general survey will first be given of this branch of the law (section II).

II. ASCERTAINMENT OF PATERNITY—A SURVEY

1. Since 1977 a distinction is no longer made in Swedish law between children born in and out of lawful wedlock; the terms "legitimate" and "illegitimate" children have been wholly discarded. Instead statute now only lays down that the husband is to be regarded as the father of a child if

[6] Bayes's theorem is a proposition concerning so-called conditioned probabilities (the principle of inversion) formulated by Thomas Bayes, a clergyman living in England in the 18th century. Concerning the feasibility of using Bayes's theorem in assessing forensic evidence, see Finkelstein & Fairley, "A Bayesian Approach to Identification Evidence", 83 *Harvard Law Review* 1970, pp. 489 ff. For criticisms, see Tribe, "Trial by Mathematics: Precision and Ritual in the Legal Process", 84 *Harvard Law Review* 1971, pp. 1329 ff. See also Gerjuoy, "The Relevance of Probability Theory to Problems of Relevance", 18 (No. 1) *Jurimetrics Journal* 1977, pp. 1 ff., and Finkelstein, *Quantitative Methods in Law: Studies in the Application of Mathematical Probability and Statistics to Legal Problems,* New York 1978.

the mother was married to him at the time of its birth. The same rule applies where the mother is a widow and the child is born within such a period of time after the death of the husband that it could have been conceived before his death (ch. 1 sec. 1 of the Parent and Child Code). The rule *pater est quem nuptiae demonstrant* accordingly no longer applies when a child is born at such a time after a *divorce* that it might have been begotten by the former husband.[7]

Under current Swedish law paternity must therefore be ascertained in accordance with special procedures—namely by acknowledgement or by judgment—unless the mother was married at the time of birth or had then recently become a widow. In those cases ch. 2 of Parent and Child Code requires the municipal child welfare committee to endeavour to determine the identity of the child's father and to have paternity established. But the committee has power to discontinue a paternity investigation in certain cases defined by the statute.[8]

2. At present the number of children born out of wedlock in Sweden is very large. In 1978, for instance, 35.9 % of all children born alive had unmarried mothers.[9] In 1979 the corresponding percentage was 37.5. The proportion of children whose parents are unmarried has increased significantly during the last fifteen years, and this increase seems largely to be due to the fact that cohabitation without marriage has been on the increase in present-day Sweden.[10] Consequently, many of the unmarried mothers are cohabiting with the father of the child in circumstances reminiscent of marriage. But in these cases, too, it is incumbent on the child welfare committee to investigate the paternity question and to take steps to have paternity established, although, of course, the investigation normally is fairly simple in such cases and usually leads up to an acknowledgement of paternity by the man in question.[11] Even in those cases where the mother

[7] Discarding the terms "legitimate" and "illegitimate" children was considered as a step of some possible importance in the efforts to stamp out the prejudiced attitudes which children of unmarried mothers can still encounter. Cf. Agell, "The Swedish Legislation on Marriage and Cohabitation. A Journey without a Destination", 24 *Sc. St. L.*, pp. 9 ff. (1980).

[8] A paternity investigation may be discontinued when, for instance, it is found impossible to obtain the requisite information for deciding the question of paternity or there are special reasons for believing that the continuance of the investigation or trial would injure the child or subject the mother to a strain which might endanger her mental health. This may for instance be the case where the child was conceived in the course of rape.

[9] In 1978, the number of live births in Sweden was 93 248. The mothers of 33 512 of these children were unmarried.

[10] The number of couples cohabiting in circumstances reminiscent of matrimony now amounts to upwards of 300 000. Out of all cohabitees, some 15 % are unmarried and accordingly about 85 % married. Cf. Agell, *op. cit., supra* note 7.

[11] The acknowledgement must be in writing and must be accepted in writing by the mother (or by a guardian especially appointed for the child) as well as by the municipal child welfare committee.

neither is or has been cohabiting with the putative father, paternity will usually be established by means of an acknowledgement, but in some cases only after a blood test has been carried out, indicating that the possibility of the man being the father cannot be excluded.[12]

3. If it is found impossible to ascertain paternity by means of an acknowledgement, the child welfare committee must institute court proceedings in order to establish paternity. For the purpose of establishing paternity by judgment, statute lays down a rebuttable presumption (*praesumptio juris*) which regulates the burden of proof as regards paternity. The presumption is now of the following tenor (ch. 1 sec. 5 of the Parent and Child Code):

> Where paternity is to be established by judgment, the court shall adjudge a man to be the father, if it is proved that the man has had sexual intercourse with the mother of the child at a time when the child can have been conceived and, having regard to all the circumstances, there is a probability that the child was begotten by him.

This rule accordingly means that if the plaintiff has been successful in proving that the mother and the defendant have had intercourse during the period of conception (*factum praesumens*), then paternity (*factum praesumendum*) need not be proved, but it is sufficient for success that paternity is made out as "probable" (a positive assessment of probability). By contrast, before January 1, 1970 the presumption, once intercourse had been proved, had the effect of shifting the burden of proof as regards the paternity from the plaintiff to the defendant. For if intercourse had been proved the paternity claim was then certain to succeed unless the defendant was able to prove that it was "improbable" that he was the father of the child (a negative assessment of probability).

The transition at the turn of the year 1970–71 from a negative to a positive assessment of probability—which was simultaneous with the extension to all illegitimate children (or now "children of unmarried mothers") of full succession rights after the father—was aimed at creating more reliable decisions in paternity suits. This was also the aim of another rule then introduced to the effect that all those men who, upon the

[12] The child welfare committee has no legal power, however, to compel a blood test. Should any of those involved in the paternity matter refuse to undergo a blood test, an action for the establishment of paternity must accordingly be commenced. For pursuant to an Act of 1958 concerning Blood Tests etc. in Paternity Investigations the court, in the course of its inquiry into a paternity question, has power on penalty of a fine to order the mother, the child and any defendant as well as any other man who may be suspected of having had sexual intercourse with the mother during the period of conception to undergo a blood test. Concerning blood tests, cf. below in the text at pp. 174 ff.

available evidence, could possibly be suspected of fatherhood as regards the child must be made defendants to the action. (Before 1970 only one man at a time could be sued.) A study of the *travaux préparatoires* of the amendment shows that, where several men have been sued, the paternity claims should be dismissed in respect of all the defendants if the evidence does not lead to any reasonably clear preponderance of probability against any one of the men.[13]

The evidence concerning the question whether or not intercourse took place between the mother and a putative father usually takes the form of oral testimony of the parties. Properly speaking, the requirement of intercourse involves two separate evidential problems, namely first, whether any intercourse at all has taken place between the mother and the defendant and secondly, whether the intercourse took place at a time when conception could have occurred. Since no legal period of gestation has been laid down by Swedish law, the court must in each case decide the question whether the child, considering its degree of development at the time of birth, could have been conceived at the alleged time of intercourse. As regards the requirement of intercourse, the wording "time when the child can have been conceived" is nowadays interpreted as meaning any time when, according to the current state of medical knowledge, it is at all possible that the child could have been conceived. The requirement of intercourse will accordingly be considered proved in a particular case even if the period of pregnancy appears extreme, but the latter fact may be given importance in connection with the assessment of probability, which is also to be made.

In assessing the probability, the credibility of the mother's testimony as to the number of men with whom she has had intercourse during the period of conception is, of course, of central importance. Using statistical methods I have tried to investigate the actual credibility of the mothers in this respect in Swedish paternity suits.[14] For in cases where a blood test has been carried out, it is possible to estimate the frequency of undisclosed instances of fertilising intercourse with the aid of information regarding (*a*) the number of men excluded on account of the blood test and (*b*) the so-called mean probability of exclusion of non-fathers[15] applicable to the particular blood test. In two samples, which I have studied—one from the

[13] Government bill 1969: 124, pp. 82 f.

[14] See Saldeen, *Fastställande av faderskap*, pp. 95 f. See, too, Malmer, "Synpunkter på faderskapsmålen", *SvJT* 1951, pp. 737 ff., Henkow, "Promiskuitet och felaktiga domar i faderskapsmål", *SvJT* 1952, pp. 382 ff., Jacobsson, "Förtegade faderskapsmöjligheter" in *Festskrift till Per Olof Ekelöf*, Stockholm 1972, pp. 396 ff., and Lind, *Faderskap och arvsrätt*, 2nd ed. Stockholm 1975, pp. 43 f.

[15] As to the mean probability of exclusion of non-fathers, cf. below in the text at p. 175.

period 1960–1964 and the other from the year 1970—the frequency of undisclosed instances of fertilising intercourse among the blood-tested one-man cases (i.e. cases where the mother had only named one man) could be estimated at approximately 12% and 20%, respectively. This indicates that the credibility is not particularly high.[16]

Other factors which may have significance in the assessment of probability in paternity actions are the result of the blood test, information concerning the length of pregnancy, the procreative power of the man, the timing of the intercourse within the menstrual cycle of the mother and sometimes (particularly in cases with more than one defendant) the use of contraceptives and the frequency of intercourse. Only the two first-mentioned factors, which generally speaking are the most important, will be the subject of detailed discussion in this essay.

III. A MODIFIED METHOD FOR CALCULATING THE PROBABILITY OF PATERNITY ON THE BASIS OF THE PATERNITY INDEX

1. The discovery by the Austrian physiologist Karl Landsteiner around the year 1900 that all individuals can be classified in accordance with their various hereditary blood groups has, of course, been of extraordinary importance for the determination of paternity. Landsteiner found two different properties of the red blood cells (the erythrocytes) of man which he referred to as A and B; he also noted that a particular individual either had the characteristic A (blood group A) or B (blood group B) or neither of the two (blood group 0). It was later found by other scientists, however, that certain individuals possess characteristic A as well as B (blood group AB) and that blood group A can be subdivided into two subgroups (A_1 and A_2). After the discovery of this blood group system—the so-called ABO system—a number of systems of blood groups, serum groups and isoenzyme groups have been successively detected and are still being detected.[17]

The main advantage of the blood test in the investigation of paternity is its faculty of excluding from the circle of possible fathers a man falsely

[16] Concerning the question how the calculation was made, cf. below in the text at note 35. The frequency of cases where the mother has had sexual intercourse during the conception period with two or more men and yet admitted intercourse with the named man only, cannot be estimated unless an arbitrary assumption is made as to how often mothers, who in reality have had relations with two or more men, have managed to name the true father in the one-man cases.

[17] On blood investigations see, e.g., Boorman & Dodd, *Blood Group Serology*, London 1970, and Giblett, *Genetic Markers in Human Blood*, Oxford and Edinburgh 1969.

named, and to do so with a high degree of certainty.[18] Such exclusion takes place when the man indicated lacks a blood factor which the child must have inherited from its father.

By way of example of exclusion according to the AB0 system may be mentioned the case where the mother has blood group B, the child blood group AB and the alleged father blood group 0. In this case the child must have inherited the A blood factor from its father, and since a group 0 man lacks this factor the man in question cannot be the father of the child in this case.

As regards exclusion by means of a blood test, the term "mean probability of exclusion of non-fathers" is used and denotes the probability of a falsely named man being excluded by virtue of a blood test. In Sweden the cumulative mean probability of exclusion is at present about 87 % in routine blood tests comprising 12 different systems. (Each particular system which is investigated has its own mean probability of exclusion. That of the AB0 system is about 15 % if the subgroups of blood group A are not taken into account.) This therefore means that out of 100 falsely accused men, some 87 can be excluded by means of blood tests. In the case of so-called extended serological investigations the average cumulative probability of exclusion reaches percentages of 95–99. These investigations, which are only carried out in special cases, comprise tests of further systems but cannot be used in routine testing on account of the high costs, complications with regard to the transportation of samples, the restricted availability of reagents (antisera) or for other reasons.[19]

When the State Institute for Blood Group Serology, where all blood investigations for the ascertainment of paternity are centralised in Sweden, made its first blood investigation in 1929, the mean probability of exclusion of non-fathers only amounted to some 15 % since the tests at that time comprised only the ABO system. Subsequently, the mean probability of exclusion has risen continuously as further systems were discovered and became available for investigation.

From the mean probability of exclusion there must be distinguished the actual probability of exclusion which indicates how often exclusions are actually forthcoming. Thus in 1972 the last-mentioned frequency in one-man cases in Sweden was about 20 %. The reason why the actual probabili-

[18] Deviations from the expected pattern of descent are, admittedly, possible, but they are so rare that the biological certainty is very high. By way of example it may be mentioned that the certainty is 99.99 % in the case of the AB0 system.

[19] If the extended serological investigation comprises the antigens of the HLA (Human Leukocyte Locus A) system, the probability of exclusion amounts to 99 %, otherwise to approximately 95 %.

ty of exclusion was considerably lower than the mean probability is, of course, the fact that the mother has indicated the true man in most paternity matters where a blood investigation has been made.

If a named man has been excluded as a result of the blood test, the paternity investigation will normally be discontinued as far as he is concerned. Consequently, in those cases which are litigated the position in Sweden now is that blood tests have been duly made with the result that it has not been possible to exclude the defendant or defendants.[20] The fact that it has not been possible to exclude a defendant by means of the blood test constitutes some evidence of a circumstantial character that he has been truly named, since the probability of a falsely indicated man being excluded is on average as high as nearly 90 %.[21]

In assessing the probability of a non-excluded defendant being the father of the child, the court may in some cases be assisted by the *paternity index*, to which we will presently turn our attention. On the basis of this index, the paternity probability of the man whose blood has been tested can be estimated and will be expressed both as a percentage and verbally.[22]

2. In 1938 the Swedish medical scientist E. Essen-Möller was able to present a method or formula, according to which the *a posteriori* probability of a named man being the father can be calculated with the aid of Bayes's theorem and with the knowledge of both the frequency of men in the whole population who possess the hereditary characteristics of the indicated man (y) and the frequency in the same population of true fathers with these characteristics (x).[23] The *a posteriori* probability in this case indicates how the probability has changed, i.e. whether it has increased or decreased when the genetic evidence has been taken into account. In this formula Essen-Möller put the *a priori* probability at 0.50, which may be expressed by the proposition that the *a priori* probability of the named man being the father is the same as the probability of some other man being so.

In 1956 the Danish forensic anthropologist Gürtler suggested a modification of Essen-Möller's formula for purposes of blood group statistical evaluation.[24] In Essen-Möller's formula the quotient of y/x is formed, i.e.

[20] As to the power to compel a blood test under Swedish law, see note 12 above.
[21] It should be noted that the probability of exclusion *in casu*, i.e. with regard to the mother-child constellation in question, can differ considerably from the average one.
[22] The paternity index and the probability of paternity with reference thereto are nowadays always stated in the expert report on the blood test if it has not been possible to exclude the investigated man.
[23] See Essen-Möller, "Positiv faderskapsbevisning", *Medicinsk Tidskrift* 1938, pp. 161 ff., and Essen-Möller & Quensel, "Zur Theorie des Vaterschaftsnachweises auf Grund von Ähnlichkeitsbefunden", *Deutsche Zeitschrift für die gesamte Gerichtliche Medizin* 1939, pp. 70 ff.
[24] Gürtler, "Principles of Blood-group Statistical Evaluation of Paternity Cases at the University Institute of Forensic Medicine, Copenhagen", *Acta Medicinae Legalis et Socialis*, vol. IX, 1956, pp. 83 ff.

the ratio of the average frequency of the occurrence of a particular blood group constellation in cases where the man is not the father of the child (y) and the same frequency in cases where he is the father (x). Gürtler found that it was more convenient, for certain reasons, to form the quotient of x/y instead. Gürtler chose "paternity index" as a name for this quotient. The modified formula of Gürtler was accepted in Scandinavia and it is accordingly the said paternity index which forms the basis of the blood group statistical evaluation in Sweden.

It will follow from the exposition below that, assuming the *a priori* paternity probability of the named man being 0.50, his *a posteriori* probability with reference to the magnitude of the paternity index can be calculated simply as his index divided by the sum of the indices of all the men who can possibly be suspected in the actual case.[25]

Let us assume that the mother has indicated only one man. Let $p(T)$ be the *a priori* probability that the true man has been named,

$p(F)$ the *a priori* probability that another man is the father (so that obviously $p(F)=1-p(T)$),

$p(x|T)$ the probability of the occurrence of a particular blood group constellation x in families where the man is the father of the child and

$p(x|F)$ the probability of the same blood group constellation occurring in cases where the man is not the father of the child. The Bayesian method of calculating the *a posteriori* paternity probability $p\ (T|x)$ may then be said to result in the following equation (formula 1 : 1):

$$p(T|x) = \frac{p(T) \cdot p(x|T)}{p(T) \cdot p(x|T) + p(F) \cdot p(x|F)}. \qquad (1:1)$$

Let us now introduce the simplification of assuming that the probability of the true man being named amounts to 0.50 only, implying that there exists an "unknown" man who might instead be the father of the child and that the *a priori* probability of this is equal to that applicable to the indicated man, i.e. 0.50. Then—since in that case $p(T)=p(F)$—the above formula might be expressed in a more simplified fashion, namely as follows (formula 1 : 2):

$$p(T|x) = \frac{p(x|T)}{p(x|T) + p(x|F)}. \qquad (1:2)$$

The value of the fraction expressing the paternity probability will not, of course, be altered if the numerator and the denominator are both divided

[25] Cf. Valentin, "Statistisk bedömning i faderskapsärenden med hjälp av faderskapsindex", in *Socialstyrelsen redovisar* 1976: 4, pp. 124 ff.

by the same quantity. If such a division is carried out, we arrive at the following (formula 1 : 3):

$$p(T|x) = \frac{\dfrac{p(x|T)}{p(x|F)}}{\dfrac{p(x|T)}{p(x|F)} + \dfrac{p(x|F)}{p(x|F)}}. \qquad (1:3)$$

Since $p(x|F)/p(x|F)=1$, formula 1 : 3 may also be written as follows (formula 1 : 4):

$$p(T|x) = \frac{\dfrac{p(x|T)}{p(x|F)}}{\dfrac{p(x|T)}{p(x|F)} + 1}. \qquad (1:4)$$

Now the paternity index is precisely the quotient $p(x|T)/p(x|F)$. Formula 1 : 4 can therefore equally well be expressed as: index/(index + 1).

The above may be illustrated by means of the calculation of the paternity index and the paternity probability in a specific case where, for the sake of simplicity, the blood test is assumed to comprise only one system, say the *MN* system. We assume that the blood investigations show that the mother belongs to blood group *M*, the child to group *MN* and the named man to group *N*. In this case the child must have inherited the *N* factor from its father, and this factor is found both in men belonging to blood group *N* and in men belonging to blood group *MN*. (A man belonging to blood group *M* lacks the *N* factor and can accordingly be excluded in the present instance.) Concerning the distribution of blood groups in the Scandinavian population, given the mother-child constellation in question (i.e. mother *M* and child *MN*), it is known that the true father belongs to blood group *N* in 44.5 % of all cases and to blood group *MN* in 55.5 % of all cases. However, if we disregard the mother-child constellation, the frequency of men possessing blood groups *N* and *MN*, respectively, in the Scandinavian population differs from those just mentioned. Thus group *N* occurs with a frequency of 20 % and *MN* with a frequency of 50 % in the entire Scandinavian population. Since the named man in the example above has blood group *N*, his paternity probability—applying formula 1 : 1 above and assuming that there exists an unknown man who might be father and whose *a priori* probability is equal to that of the indicated man, i.e. 0.50—will be as follows:

$$p(T|x) = \frac{0.50 \times 44.5}{0.50 \times 44.5 + 0.50 \times 20} = 0.69 (= 69\,\%).$$

Since the paternity index in the present case is precisely the quotient 44.5/20, i.e. 2.2, it follows from formulae 1 : 2–1 : 4 above that the paternity probability in this case also may be calculated as 2.2/(2.2+1)=0.69(=69 %).

In the specific example above we assumed that the blood test only comprised one blood group system. In reality several different systems will, of course, be investigated. The overall paternity index of the blood-tested man will be obtained by multiplying the various index values.

The paternity index, which may assume values from 0 (i.e. the index for excluded men) to infinity, discriminates between fathers and non-fathers by conferring on fathers, on average, higher paternity indices than on non-fathers. Index 1 represents the neutral value (the mean paternity index for non-fathers) and thus implies, as far as the investigated characteristics are concerned, that the child and the named man resemble each other exactly as much as one might expect the child to resemble a man indicated at random. It should be emphasized that the paternity index implies that the resemblance between the child and the named man is related to the expected degree of similarity between the child and a man chosen at random from an *average* population of Swedish men. If the indicated man belongs to a population whose genetical composition differs from that of the Swedish average, then the paternity probability might become drastically distorted. Kinship, too, distorts the paternity probability.

If the mother has named only one man and the latter has been given a paternity index of 19 and there is reason to reckon with only one unknown man, then the paternity probability of the indicated man is 95 % (given an *a priori* probability of 0.50). For 19/(19+1)=0.95(=95 %). (If there are grounds for taking into account more than one unknown paternity possibility, an index of 19 will not produce a paternity probability of 95 %. Where for instance there are two unknown men, the paternity probability of the indicated man will be only 90 % (19/(19+1+1)=0.90).) If instead the paternity index of the named man only amounts to 0.053 but the assumptions otherwise are as in the preceding example, the paternity probability will be only 5 % (0.053/(0.053+1)=0.05). As only values of 95 % or above are considered statistically significant (so-called significance at the 5 % level), it follows that only a paternity index of at least 19 can, standing by itself, be regarded as proof of paternity, provided that there is only one unknown man and the *a priori* probability of his being the father of the child is the same as for the indicated man. (An *a posteriori* paternity probability of 95 % means that if the court allows the paternity claim to succeed, the risk of an error, i.e. the risk that the claim is erroneously accepted (type I error), does not exceed 5 %.)

In the same circumstances only an index as low as 0.053 (paternity probability 5 %) can in itself be regarded as evidence against paternity. The general view is that significance can hardly be attached to a paternity index in itself if it amounts to anything between 19 and 0.053. If there are two known (blood-tested) possibilities of paternity, only a ratio of the indices of the two men exceeding 19 to 1, i.e. 95 % to 5 %, is in itself regarded as indicative of the paternity of one man rather than the other. (Thus, if, for instance, A's index is 8, B's index must amount to 152 (19×8) in order to make the difference between the men's indices sufficiently significant (152/(152+8)=0.95).) In a case where there are more than two blood-tested paternity possibilities, the ratios of the paternity probabilities of the various men to each other may be calculated in a corresponding way.

As explained above paternity indices which may be regarded as decisive evidence are not, however, often encountered. Should the court then disregard the paternity index in other cases? The answer must be "no", since this can hardly be the intention of the legislation. The exposition above of the method for calculating the paternity probability on the basis of the paternity index demonstrates that the answer to the question, "Which paternity index results in a sufficiently significant paternity probability?" is dependent on the *a priori* probability that is employed. If it is assumed in a one-man case that the *a priori* probability of the defendant being the father differs from 0.50, then obviously an *a posteriori* probability of 95 % and 5 %, respectively, may be obtained by indices other than 19 and 0.053. And further, where there are several defendants, a ratio of the indices of the men falling below 19 to 1 might be relevant on the assumption that the *a priori* probabilities of the men are different. The paternity probability with reference to the magnitude of the paternity index set out in the expert opinion will naturally be calculated on the basis of an *a priori* probability of 0.50 (50 %), since the expert has not had access to any information of significance for assessing the paternity question other than the result of the blood test.

The court, however, may be informed of circumstances other than the result of the blood test and must then take them into consideration so that it may arrive at a more realistic *a priori* probability than 0.50 in the particular case. If the court were then to act in a strictly formal way, the value of this estimated *a priori* probability should be inserted in the formula for calculating the *a posteriori* probability. Suppose, for instance, that a sole defendant has a paternity index of 6.5. This will result in an *a posteriori* probability of only 87 % (0.866), assuming an *a priori* probability of 0.50. But if the court puts the *a priori* probability of the defendant being the father at, say, 0.75 (75 %), then the same index produces an *a posteriori* probability of 95 % in accordance with the following calculation:

$$p(T|x) = \frac{0.75 \times 6.5}{0.75 \times 6.5 + 0.25 \times 1} = 0.95.$$

Unfortunately, however, the court's chances of making a realistic assessment of the defendant's *a priori* probability on the basis of the particular circumstances of the case must be regarded as limited.[26] It is sufficient to refer to the difficulties of estimating the mother's credibility correctly, of deciding the exact importance to be assigned to other circumstances and the resulting intricacies of collectively evaluating the cogency of the various proofs. The difficulty of assessing the *a priori* probability by means of an individual estimate is the reason why an attempt is made below to develop a modified method of calculating the *a posteriori* paternity probability in defended paternity actions with one defendant. The method involves an attempt to calculate a realistic collective *a priori* probability for a specific sample of paternity cases and to do so with the aid, *inter alia,* of the mean probability of exclusion applicable at the time of the particular blood test.[27]

3. An a priori probability of 0.50 for a defendant in a one-man case can be explained thus: in a sample consisting of N paternity matters the defendant will be truly named in one half of the cases and consequently falsely named in the other half. If the proportions of fathers and non-fathers in the sample are different, the *a priori* probability of 0.50 is obviously not warranted. Knowing the mean probability of exclusion applicable at the time of the blood test and the proportion of actually excluded men in the sample, an approximate calculation can be made of the proportions of fathers and non-fathers in the material.

[26] The term "*a priori* probability" here refers to the probability of paternity for a defendant assessed on the basis of circumstances other than the paternity index, such as the credibility of the mother, the length of the period of pregnancy, the use of contraceptives and the frequency of intercourse. The words "*a priori*" are not entirely appropriate in this connection, however, among other things because the court normally possesses information as to the paternity index already at the time when it evaluates the probability of paternity with regard to the other evidence. There is a risk which cannot be disregarded that the last-mentioned probability in reality will be influenced by the knowledge of the size of the paternity index.

[27] As to earlier attempts to modify the methods for assessing the *a priori* probability, see e.g. Hummel, *Die medizinische Vaterschaftsbegutachtung mit biostatistischem Beweis*, Stuttgart 1961. Cf., e.g., Grumbrecht, *Der Beweis der "offenbaren Unmöglichkeit" der Vaterschaft*, Cologne-Berlin-Bonn-Munich 1967, pp. 56 ff.

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In the model for calculating the *a posteriori* paternity probability which will be suggested in this essay, the starting point is a population of N paternity matters with only one indicated man (one-man matters). We assume that a blood investigation is made in all cases and that all the men deny paternity before the blood test. This population of N cases can be split into two subpopulations, one consisting of N_T fathers and the other of N_F non-fathers.

Let the mean probability of exclusion for non-fathers be designated "e". The number of men who will be excluded through the blood test we will designate as "E". This number E is a random variable with an expected value of eN_F (i.e. e multiplied by N_F). If N_F is not too small, E will tend to approximate this expected value. We can therefore formulate the approximate equality

$$eN_F = E.$$

The number of men who have not been excluded by means of the blood test (i.e. $N-E$) may be expected to amount to $N_T+(1-e)N_F$. In expectation the following therefore applies (formula 2):

$$N-E = N_T+(1-e)N_F. \tag{2}$$

When the result of the blood test is available, it may be expected that some of the named men who have not been excluded, will admit paternity. As regards those men who have been excluded in consequence of the blood test, we assume that the paternity investigation is discontinued. With regard to those cases where a law suit is contemplated, there is reason to suppose that a falsely named man who has not been excluded by the blood test is more likely to deny the allegation of paternity than is a truly indicated man. We designate the first-mentioned probability as "k_F" and the last-mentioned probability as "k_T". It is reasonable to expect that the following holds good:

$$k_F \geqslant k_T.$$

The number of defended paternity actions will now be designated "D". In expectation the following will then apply (formula 3):

$$D = k_T N_T + k_F(1-e)N_F. \tag{3}$$

In the defended paternity actions the defendant will in some cases be the true father and in some cases falsely accused. That portion of the cases where the defendant is the father is designated "Q_1". The portion where the man is falsely indicated will then be $1-Q_1 \cdot Q_1$, which may be regarded as an *a priori* probability of paternity in defended paternity suits, may accordingly be expressed as follows:

$$Q_1 = \frac{k_T N_T}{k_T N_T + k_F (1-e) N_F};$$

or as follows:

$$Q_1 = \frac{k_T f}{k_T f + k_F (1-e)(1-f)},$$

where

$$f = \frac{N_T}{N_T + N_F} = \frac{N_T}{N}.$$

The conditional probability of finding the blood group constellation "x" with a non-father, provided that he has not been excluded as a possible father by the blood test, may be expressed as $p(x|F)/(1-e)$. It now follows from Bayes's formula (formula 1 above) that the *a posteriori* probability in defended paternity actions is contained in the expression (formula 4):

$$p(T|x) = \frac{Q_1 \cdot p(x|T)}{Q_1 \cdot p(x|T) + (1-Q_1) \cdot p(x|F)/(1-e)}. \quad (4)$$

If we define Q as follows (formula 5):

$$Q = \frac{k_T f}{k_T f + k_F (1-f)}, \quad (5)$$

and take advantage of the characteristic of $L(x)$ (which we define as the paternity index) that $L(x) = p(x|T)/p(x|F)$—see section III: 2 above—then it will be seen that the *a posteriori* paternity probability in defended paternity suits may be formulated as follows (formula 6):

$$p(T|x)=\frac{Q\cdot p(x|T)}{Q\cdot p(x|T)+(1-Q)\cdot p(x|F)}=\frac{Q\cdot L(x)}{Q\cdot L(x)+(1-Q)}. \qquad (6)$$

The true value of Q (in formula 5) will be unknown in practice but it follows from the reasoning above that it is possible to obtain an approximate value of Q with the assistance of suitable data. On the basis of data concerning the following variables, Q can in fact be calculated:

N = the total number of cases where the named man has undergone a blood test;
E = the number of men excluded by reason of the blood test;
e = the mean probability of exclusion at the time of the investigation;
D = the number of defended paternity actions and
$L(x)$ = the paternity index.

A comparison with Bayes's formula (formula 1) demonstrates that Q, consequently, can be regarded as an *a priori* probability of paternity, i.e. in this connection the paternity probability which applies before the blood group statistical evidence (the paternity index) is taken advantage of.

If it is desired to utilize the *a posteriori* probability $p(T|x)$ in calculating the probability in paternity suits of the one-man type, formula 6 above can be used as a guideline. With the aid of the example below I shall try to render the reasoning above more specific.

Suppose that we possess a sample consisting of 1 100 named men who had been blood-tested in respect of the hapto-globin system (the Hp system). As a result altogether 18 men were excluded. As regards the index possibilities, the 1 100 men are distributed in the manner set out on Table I below.[28]

Table I. *Index distribution for 1 100 blood-tested men as regards the Hp system and the* a posteriori *paternity probability.*

T = number of true fathers, F = number of non-fathers, $p(T|x)$ = the *a posteriori* paternity probability (according to formula 6).

Possible indices	T	F	$T+F$	$p(T\|x)$	$\frac{T}{T+F}$
0.000[a]	0	18	18	0	0
0.8078	180	22	202	0.89	0.89
1.000	236	24	260	0.91	0.91
1.312	180	14	194	0.93	0.93
1.616	293	18	311	0.942	0.942
2.625	111	4	115	0.964	0.965
Total:	1 000	100	1 100		

[a] Excluded men.

[28] The information concerning the index distribution as regards the Hp system has been taken from a doctoral thesis by Kataja, *Simulation in Paternity Analysis*, Helsinki 1975.

If we assume that $k_T = k_F$, i.e. that all those men who have not been excluded by the blood test deny paternity, then $Q = 10/11$ which, of course, corresponds to the occurrence of fathers and non-fathers in the sample. Thus, the *a priori* probability would here be equivalent to the probability of a man indicated at random among the 1 100 men being father, i.e. 1 000/ 1 100.

In order to calculate the *a posteriori* probability we now form the following quotient (formula 7):

$$p(T|x) = \frac{QL}{QL + 1 - Q}. \tag{7}$$

Applications of this expression will be found in the penultimate column of Table I. Consequently, the *a posteriori* probability calculated in this way corresponds—apart from rounding-off errors—with the ratio of the number of true fathers to the sum of alleged fathers in the last column of Table I. As is demonstrated by these last two columns, the value rises with increasing index values.

The above example is, of course, hypothetical, since we must know the proportion of true fathers among the accused men in the sample in order to be able to calculate Q in formula 7. In the example above, $N = 1\,100$, $N_T = 1\,000$, $N_F = 100$, $e = 0.18$, $E = 18$, $D = 1\,082$, $k_F = k_T = 1$ and $Q = f = 10/11$.

In a practical situation we will only have access to values for N, e, E and D. As regards k_F and k_T, it may be most convenient to make use of the following alternative assumptions—though other alternatives are conceivable—namely $k_F = k_T$, i.e. the tendency to deny paternity is the same among true fathers as among non-fathers (alternative I), and $k_F = 1$, i.e. all non-fathers deny paternity (alternative II).

Employing formulae 2 and 3, we arrive at the following values for Q on the basis of the alternative assumptions just mentioned:

Alternative I, i.e. $k_F = k_T$, (formula 8):

$$Q_{\text{I}} = 1 - \frac{E}{eN} \quad \text{and} \tag{8}$$

Alternative II, i.e. $k_F = 1$, (formula 9):

$$Q_{\text{II}} = 1 - \frac{E}{e(D+E)}. \tag{9}$$

If we again consider the material presented in table I and make the assumption that we only know that $N = 1\,100$, $e = 0.18$, $E = 18$ and $D = 1082$, we arrive at the following estimates as regards Q according to alternatives I and II:

$$Q_{\mathrm{I}} = 1 - \frac{18}{0.18 \times 1\,100} = \frac{10}{11} \text{ and}$$

$$Q_{\mathrm{II}} = 1 - \frac{18}{0.18 \times (1\,082 + 18)} = \frac{10}{11}.$$

In this made-up example Q_{I} and Q_{II} thus happen to coincide with the true (though unknown) value of Q, namely 10/11. In other samples the values of Q_{I} and Q_{II} may well differ from each other (cf. below).

Q_{I} accordingly represents the *a priori* probability of an accused man being a true father when fathers and non-fathers have the same tendency to deny the paternity claim and Q_{II} is the *a priori* probability of an accused man being a true father when all non-fathers deny paternity. However, the last alternative is probably less realistic, since the accused man usually cannot be assumed to have any definite notion as to the true facts in regard to the paternity question.

Let us now apply the suggested model to a sample of first instance court cases. It consists of 354 one-man matters in which blood specimens were received by the State Institute for Blood Group Serology in the year 1970. In 61 of these matters the named man could be excluded by means of the blood test. When the remaining 293 paternity cases were followed up, it was found that the paternity question had been tried by a court in 95 cases, out of which some 60 were defended. The mean probability of exclusion amounted to 87 % in 1970. The relevant variables will accordingly receive the following values: $N=354$, $E=61$, $D=60$ and $e=0.87$. It follows from formula 2 that the number of non-fathers in the material may be estimated at 70.11 (with a confidence at the 95 % level, the true value lies somewhere between 66 and 75), out of whom 61 had accordingly been excluded, and that we may expect the number of true fathers in the material to be 283.9. The proportion of true fathers in the material can accordingly be estimated at 283.9/354=0.80 or 80 %.

If the tendency to deny the paternity claim was the same among true fathers as among non-fathers (alternative I), then the proportion of true fathers in the defended paternity cases should be 0.80. This means that where alternative Q_{I} is selected even a paternity index of 4.70 gives rise to an *a posteriori* probability of paternity of 95 %; an index of 0.013 gives an *a posteriori* probability of 5 %. If instead true fathers and non-fathers have different inclinations to deny the paternity claim, the proportion of true fathers in the defended paternity actions should be different. According to formula 9 (alternative II) Q_{II} will be 0.42, implying that the paternity index instead must amount to 26.18 in order to produce an *a posteriori* probability of 95%; an index of 0.073 creates a probability of 5%. But, as already stated, alternative II is probably less realistic than alternative I.

The application of the model here presented for calculating the *a posteriori* probability of paternity on the basis of the paternity index in a particular sample of paternity cases presupposes, *inter alia*, that a blood investigation has been made and that it has been possible to calculate the proportion of true fathers and non-fathers in the material, with the assistance of the mean probability of exclusion and other factors. In order to enable the courts to make use of the model, it is desirable that some public authority—in Sweden the State Institute for Blood Group Serology would be the appropriate one—calculates the proportions referred to and that the courts do not determine the question of paternity in any of the cases belonging to the investigated material until they have been informed thereof. For various reasons, it would be difficult to meet these requirements in practice. But if it were possible, by means of investigations carried out intermittently, to demonstrate that the proportions of true fathers and non-fathers in paternity cases is tolerably constant, and if it were also possible to replace the assumptions made here concerning the tendency of true fathers and non-fathers to deny paternity with more certain knowledge as to these particulars, then it would be comparatively easy to calculate the value of Q, which is necessary for the use of the model, and the latter could then be of immediate importance in the administration of justice.

In the above study I have considered only blood test results and have disregarded other items which may be of importance in calculating the probability of paternity. I have done so since it is not clear what weight should be accorded to them and how the relative importance of the various factors is to be estimated. But in principle it is, of course, quite possible to adjust the *a priori* probability—collectively calculated with the aid of the model—with reference to the special circumstances of the case in hand.

IV. THE VALUE OF DURATION OF PREGNANCY INFORMATION IN ASCERTAINING PATERNITY

1. As has already been pointed out, the circumstance that the period of gestation is extreme may assume importance in the assessment of probability in paternity cases. In Sweden the courts (or the municipal child welfare committees) often request the National Board of Health and

Welfare to give an expert opinion as to the probability of a child being conceived at a certain point of time, having regard to its development at the time of birth (i.e. its length and weight). For the purposes of this assessment there is nowadays used in Sweden a statistical material, collected in the mid-fifties and processed by Engström and Falconer, concerning the birth length and weight of some 59 000 children born in lawful wedlock and with known gestation periods.[29] The earliest and latest points of time at which the child can possibly have been conceived are then estimated by correlating the child's weight and length at birth with the stated time of conception. The outcome will be probabilities (in the form of percentages) that a child selected at random and having at birth the length and weight in question was conceived before or after the stated point of time. Properly speaking, however, such a computation should only be used provided that the totality of cases going to court exhibits a distribution which differs from that of the material used for reference or comparison, namely the Engström-Falconer tables, by comprising a considerably greater number of cases at the outer limits of the scale.

The principal aim of the jurimetrical investigation to be presented below was, by studying a number of first instance judgments in paternity matters, to obtain a more reliable notion of the value of probability assessments of the kind described above in cases where the blood test has not excluded the named man. Another aim was, if possible, to arrive at a practicable percentage limit for the calculation of probabilities.[30] It may be mentioned that at the time of the investigation the Royal Board of Medicine (now the National Board of Health and Welfare) considered that the level of "non-probability" should be fixed at 10%. According to a pronouncement in legal writing in 1970, the paternity claim should be dismissed if the percentage pursuant to the Engström-Falconer tables did not exceed 5, unless other circumstances in the case indicated some other conclusion.[31]

2. The sample consists of first instance judgments pronounced during the period 1960–1964. 511 cases make up the sample. In 295 of these the defendant denied the paternity claim, and acknowledgements were accordingly recorded in the remaining 216 cases.

Blood-testing was performed in a total of 373 cases where the mother had named only one man. The accused man could be excluded in 28 of these cases. The 28 cases are, of course, without interest in an investigation

[29] The Engström-Falconer tables are set out in *SOU* 1965: 17.
[30] This investigation was carried out in co-operation with Professor G. Eklund and Professor T. Saldeen. Cf. Eklund *et al.* in *SvJT* 1971, pp. 538 ff., and in *Zeitschrift für Rechtsmedizin* 1971, pp. 252 ff.
[31] Lind, *Faderskap och arvsrätt*, 1st ed. Stockholm 1970, p. 52.

on exclusion from paternity based on evidence concerning the duration of pregnancy. The cumulative mean probability of exclusion (cf. section III: 1 above) was about 64%. This means that among the 373 blood-tested cases the number of cases where the paternity claim ought to have been dismissed can be approximately calculated by forming the quotient 28/0.64, i.e. 44 cases. This implies that the named man was falsely accused in some 16 cases in addition to the 28 where he was excluded by means of the blood test.[32] These 16 cases only constitute some 5% of the 345 cases remaining after the exclusion of the 28 cases. This is a remarkably low figure and indicates that the paternity claim would have succeeded in 95% of the remaining blood-tested cases if the truth had been known. This therefore demonstrates that the paternity claim should be dismissed only in a small number of cases by reference to an extreme period of gestation.

On the basis of the recorded information concerning the length and weight of the children at birth, probabilities—referred to below as "percentages"— of the pregnancy period being as stated or shorter/longer were calculated with the aid of the Engström-Falconer tables. Using the length and weight information it was possible, with the assistance of the said tables, to establish within which percentage ranges the observed pregnancy periods occur. The cases of short periods of pregnancy were then found to occur within the percentage range of 0–10 (very short periods within the interval of 0–0.5%) and the long ones in the interval 90–100% (very long ones in the interval 99.5–100%).

Table II shows the result of the blood tests in those cases in the sample of court cases studied where the conception date was known. The percentages were here calculated on the basis of weight and the table includes cases both where the defendant denied the paternity claim and cases where he admitted the claim in the course of the trial of the matter. It follows from the table that the proportion of cases where the defendant was excluded by means of the blood test was larger in the case of extreme periods of pregnancy than in the case of less extreme ones. This means that the cases where the paternity claim ought to have been dismissed should mainly be found among the cases exhibiting an extreme gestation period.

In 119 of the 295 defended cases information was available concerning the date of conception and the weight and length at birth, while in seven cases the two first-mentioned data were known but the length was not known. The investigation described immediately below was accordingly concerned with in all 126 cases.

With the aid of the Engström-Falconer tables percentages based on the

[32] Cf. below under V.

Table II. *The number of defendants excluded on account of the blood test in per cent of the total number of blood-tested defendants in cases where the date of conception was known.*

Percentage range	Defendants excluded through blood test, numbers	Blood-tested defendants, totals	Excluded men, percentages
10–90	7	124	6
0–10	5	19	26
90–100	7	31	23

length and weight at birth were calculated in respect of all the 126 cases. If the cases had been representative of the material analysed by Engström and Falconer, they would have been evenly distributed (i.e. they would have exhibited a rectangular distribution between 0 and 100). If, however, the child was not conceived at the stated act of intercourse, there would be an accumulation of cases towards the outer limits of the scale, especially if the actual time of conception differed considerably from the one alleged.

Table III. *Expected and observed number of cases, and the quotient expected/observed number of cases, where paternity was denied and the conception date was known.*

	Birth length (total 119 cases)			Birth weight (total 126 cases)		
Percentage range	Ex-pected	Ob-served	Exp./ Obsd.	Ex-pected	Ob-served	Expd./ Obsd.
10–90	95.2	82	1.16	100.8	94	1.07
0–10	11.9	17	0.70	12.6	15	0.84
90–100	11.9	20	0.60	12.6	17	0.74
0–5	5.95	13	0.46	6.3	10	0.63
95–100	5.95	14	0.43	6.3	15	0.42
0–2.5	2.98	2	(1.49)	3.15	5	0.63
97.5–100	2.98	10	0.30	3.15	11	0.29
0–1	1.19	1	(1.19)	1.26	0	(~)
99–100	1.19	8	0.15	1.26	8	0.16
0–0.5	0.60	0	(~)	0.63	0	(~)
99.5–100	0.60	6	0.10	0.63	6	0.11

Table III shows the observed and the expected number of cases where the defendant denied paternity and where the date of conception appeared from the available material. On the basis of the information concerning length and weight and with the aid of the Engström-Falconer tables it was possible to establish to which percentage ranges the observed pregnancy periods were to be allocated. In the birth weight column we find, for instance, that in 94 cases the pregnancy period was to be found in the 10–90 percentage range while in six cases it was located in the 99.5–100 percentage range, i.e. the region of very long periods of gestation. The table indicates that 15 of the 126 observed children belong to the 0–10 percentage range (short periods of gestation). This is more than might be expected judging from the rectangular distribution. According to the latter, one-tenth of the material, i.e. 12.6 children, should be located in this range.

If the principle had been applied of always dismissing a paternity claim in cases where the child in question was to be found in the 0–10 percentage range, then the claim would have been dismissed in 15 of the 126 cases, i.e. in about 12% of the cases. If the same rule were applied to a normal sample consisting of children born in lawful wedlock (and where paternity is not disputed), 10% of the cases would be found within the range in question. It is therefore clear that the number of cases of disputed paternity is not greatly in excess of that to be found in an average material in this percentage range; the difference is, in fact, approximately 2% only. This means that if the above-mentioned rule were to be applied and the paternity claim dismissed in all the 15 cases, a comparison between the observed and the expected percentages would demonstrate that a correct decision was certain to be made in only 16% of those cases ((15–12.6)/15) and accordingly that there was a risk of an incorrect decision in (up to) 84% of the cases (12.6/15). The argument presupposes that indications other than the time of conception and the birth weight are disregarded. We also pass over the possibility that the extreme period of gestation may have been the reason for denying paternity, which seems rarely to be the case.

A more favourable comparison by far between expected and observed cases will be attained by confining the rule of dismissing all paternity claims to the 99.5–100% range (the range corresponding to the very longest periods of pregnancy, considering the weights at birth). Then the quotient of the expected number of cases divided by the observed number will be (0.63/6=)0.11 and an incorrect decision might be apprehended in (up to) 11% of the cases where the paternity claim has been dismissed on the strength of the rule in question.

Similar conditions seem to prevail whether the percentage calculations are based on lengths at birth or weights. Moreover, the risk of arriving at incorrect decisions appears throughout to be smaller with regard to long pregnancies (e.g. the 90–100% range) than where short ones are concerned (e.g. in the 0–10% range).

The probability of a paternity claim being unjustly dismissed has been summed up on table IV below. This probability may be estimated in two different ways:

(1) By forming the quotient of the expected number of cases divided by the observed number (columns *A* and *B*). (This method will, however, result in slightly too high a value.)

(2) By forming the ratio of (*a*) the number of cases where the defendant has been excluded by the blood test divided by 0.64 (the appropriate mean probability of exclusion) to (*b*) the total number of blood-tested cases. Provided that the judgment is based on the relevant percentage ranges only, the difference between 1 and the quotient referred to constitutes an estimate of the relative number of cases where the judgment would in fact be wrong if the paternity claim were dismissed in all cases in the percentage range in question (columns *C* and *D*).

Table IV. *Comparison between the estimated probability of an unjust dismissal of a paternity claim using* (1) *the ratio of the expected number of cases to the observed number (columns A and B) and* (2) *the ratio of (a) the number of cases excluded through the blood test divided by 0.64 to (b) the total number of blood-tested cases (columns C and D).*

A and *B* include only disputed cases, *C* and *D* both admitted and disputed ones. *A* and *C* have reference to the date of conception, *B* and *D* to the first day of the last menstrual period.

The table records cases where the weight at birth was known. The figures in brackets were based on too small a number of cases to admit of any firm conclusions.

Percentage ranges	*A*	*B*	*C*	*D*
0–10[a]	0.84	0.97	0.59	0.71
90–100[b]	0.74	0.38	0.65	0.88
0–10,[a] 90–100[b]	0.70	0.55	0.62	0.83
0–5[a]	0.63	0.61	0.44	0.73
95–100[b]	0.42	0.29	0.69	0.91
0–5,[a] 95–100[b]	0.50	0.38	0.60	0.85
0–2.5[a]	0.63	0.40	(0.13)	0.71
97.5–100[b]	0.29	0.21	0.67	0.91
0–2.5,[a] 97.5–100[b]	0.39	0.27	0.50	0.84
0–1[a]	(~)	0.45	(0.22)	0.53
99–100[b]	0.16	0.11	0.69	0.93
0–1,[a] 99–100[b]	0.32	0.18	0.55	0.80
0–0.5[a]	(~)	0.28	(0.22)	(0.48)
99.5–100[b]	0.11	0.09	(0.61)	0.90
0–0.5,[a] 99.5–100[b]	0.21	0.13	0.53	0.78

[a] Short periods of pregnancy.
[b] Long periods of pregnancy.

Columns *A* (cf. table III) and *B* show that the frequency of incorrect judgments decreases with the increasing extremity of the period of pregnancy. This tendency cannot be found in columns *C* and *D*, which may be due to the fact that the latter (unlike *A* and *B*) comprise cases where the named man has been excluded on account of the blood test. These cases are distributed among various percentage ranges. Column *C* demonstrates that the paternity claim would have been unjustly dismissed in more than one half of the cases if dismissal had taken place in all cases of extreme periods of pregnancy.

Since *A* and *B* do not comprise those cases which have been excluded on account of the blood test, these columns contain one piece of additional information beyond that appearing in columns *C* and *D*, namely that there are grounds in certain cases for dismissing a paternity claim on account of the extreme length of the pregnancy. The quotients are high, however, and therefore paternity should hardly be excluded until the period of pregnancy is so extreme as to correspond to 99.5 % (very long pregnancies). For the short periods of gestation the quotients are higher still, as shown by columns *A* and *B*, and it is doubtful if, on the basis of the material discussed here, any percentage limit can be suggested at all in the present connection. Only pregnancies of an extremely short duration should call for dismissal of the paternity claim.

To sum up, the study has demonstrated that, after a blood test, there only remains a small number of cases where a paternity claim should be dismissed on account of the pregnancy period being extremely long or short, and that only very extreme percentages should occasion a dismissal if a great risk of error is to be avoided. As far as short periods of pregnancy are concerned, it is doubtful if any percentage or permillage limit can be indicated at all that would justify excluding paternity. Some pregnancy periods of an extreme shortness might, however, be regarded as absurd. In the case of long pregnancies the 0.5 % limit (a percentage of 99.5) produces a risk of error of only 10 %, which can probably be regarded as acceptable.[33]

V. A JURIMETRICAL METHOD FOR CHECKING THE EFFICIENCY OF THE ADMINISTRATION OF JUSTICE AS REGARDS THE ASCERTAINMENT OF PATERNITY

1. It is a consequence of the considerable problems of proof in paternity cases that the possibility of erroneous judgments cannot be disregarded, so that claims have been allowed to succeed or to fail contrary to the true facts. As far as Swedish conditions are concerned, it may be expected that

[33] It seems to be a fact that the importance of information concerning pregnancy periods in assessing whether a named man can be the father or not has decreased in pace with the increased possibilities of excluding an erroneously named man through a blood investigation.

the first-mentioned type of erroneous judgment was more common before 1970 when the statutory rule on ascertainment of paternity prescribed a negative assessment of probability (cf. II: 3 above). The transition from a negative to a positive assessment of probability, applicable after 1969, may indicate that the latter type of erroneous judgment, i.e. an unjust dismissal of the claim, has instead become more frequent.

Against this background it may be of interest to note that it is possible, if a blood test has been carried out, to calculate (approximately) in how many cases out of a particular sample of paternity matters the claim ought to have been dismissed (or allowed to succeed). The computation has reference to the totality of the material analysed, but does not allow any pronouncement as to the correctness of the judgment in any particular case.[34]

2. The method thus presupposes blood-testing and is based on the principle that if, in a particular sample of paternity cases, we know the number of men excluded on account of the blood test as well as the mean probability of exclusion, we can calculate the number of men in relation to whom the paternity claim should be dismissed.

The *total* number of men in the sample who ought to be excluded from the paternity allegation can be calculated approximately with the aid of the following formula (formula 10):

$$(k-1)N_k+\frac{E_k}{e^k}, \qquad (10)$$

where k=the number of blood-tested men in each case,

N_k=the total number of cases in each of which the number of blood-tested men was k,

E_k=the number of cases where k men were excluded through the blood test and

e=the mean probability of exclusion of non-fathers when the blood test was performed.

As regards those cases in the sample where the number of blood-tested men was k, the number of men who should be excluded from the paternity allegation for some reason other than the result of the blood test can be approximately calculated in accordance with the following formula (formula 11):

[34] With reference to the text below, cf.—apart from Saldeen, *Fastställande av faderskap*—Saldeen, "En jurimetrisk metod för en rättssociologisk analys" in *Festskrift till Per Stjernquist*, Lund 1978, pp. 55 ff.

$$\frac{E_k}{e^k}+\sum_{i=1}^{k+1}(k-i)E_{i-1}, \tag{11}$$

where i can be any whole number from 0 to k, inclusively, and E_{i-1}=the number of cases in which the precise number of $(i-1)$—no more and no less—men have been excluded by virtue of the blood test.

Applying formula 11 to *one-man cases* (i.e. $k=1$), we arrive at the result that the number of men not excluded by means of the blood test yet falsely named and accordingly deserving acquittal on the paternity charge, amounts to (formula 12):

$$\frac{E_1}{e}-E_1, \tag{12}$$

where E_1=the number of cases where one man was excluded by virtue of the blood test. (And since no more than one man can be excluded in each one-man case, this also represents the total number of excluded men.)

In respect of the *two-men cases* (i.e. $k=2$), the corresponding formula is (formula 13):

$$E_0+\frac{E_2}{e^2}-E_2, \tag{13}$$

where e is the expected value of the mean probability of exclusion in respect of the N_2 two-men cases,

E_0=the number of cases in which neither of the two men could be excluded through the blood test and

E_2=the number of cases where both men could similarly be excluded. (The formula will not be affected by the number of cases (E_1) where one man but not the other has been excluded.)

If it is impossible to separate the one-man cases from those with several defendants but the total number of cases (N) and the total number of excluded men (E) are known, then the total number of men who should be excluded from paternity can be estimated at (formula 14):

$$\frac{E}{e}. \tag{14}$$

3. The aim of the following investigation is to ascertain to what extent the actual number of dismissed paternity claims corresponds to the approximate expected number of such dismissals in respect of two different samples of first-instance cases.

One sample, comprising 373 first-instance cases decided in the period 1960–1964, was drawn directly from a number of chosen courts of first instance. In 28 of the 373 cases the defendant had been excluded from paternity through the blood test. The mean probability of exclusion of non-fathers amounted to 64%. From this follows, applying formula 14 above, that the number of cases where the paternity claim ought to have been dismissed among the 373 cases may be calculated at approximately (28/0.64=)44. (The reason for using formula 14 in this instance is that no information is available as to whether any man apart from the defendant had been blood-tested.) A survey of the results recorded in the 373 cases discloses that the paternity claim was, in fact, dismissed in 40 cases; in 28 of these because the defendant was excluded on account of the blood test and in 12 for other reasons. The correlation between the approximate estimate of the number of cases where the paternity claim ought to have been dismissed (44 cases) and the number where the claim was in fact dismissed (40) must accordingly be considered as good.

The other sample, comprising first instance judgments pronounced in 1970 or later, was drawn from the 500 paternity matters which were the first to be received for testing by the State Institute for Blood Group Serology in the year 1970. For various reasons of a practical nature 50 of those matters were not further studied. Of the remaining 450 matters, 354 involved one man, 86 two men, 8 three men and 2 four men. This means that 558 blood-tested men were included in the material. Out of these, 158 were excluded on account of the blood test, namely 61 in the one-man cases and 77 in the two-men, 17 in the three-men and 3 in the four-men cases.[35]

With the aid of the formulae above it may be calculated that, out of those men not excluded by reason of the blood test, approximately 29 were nevertheless falsely named. Hence the paternity claim, if all the 400 non-excluded men had been made defendants, ought to have been dismissed as regards some 29 men. A follow-up of the paternity matters in question carried out by me at the end of 1977 showed, however, that the paternity claim had been dismissed only with regard to 13 men. But it must be taken into consideration both that the paternity question had not then been determined in the case of 10 men, and that the child welfare committee had discontinued the investigations as regards 17 men. In some of the

[35] It was mentioned on p. 174 above in the text that the writer had been able to calculate the frequency of undisclosed fertilising acts of intercourse in two different samples of one-man cases at 12 and 20% respectively. It should be clear by now how the calculation was made. One sample comprised 373 one-man cases out of which the named man could be excluded, thanks to the blood test, in 28 cases. Since the mean probability of exclusion of non-fathers amounted to 64%, 28 excluded men should correspond to approximately (28/0.64 =) 44 erroneously named men, i.e. 12% of the 373 cases. The other sample comprised 354 one-man cases out of which the named man could be excluded in 61 cases. The mean probability of exclusion amounted to 87%; hence 61 excluded men should correspond to approximately (61/0.87 =) 70 falsely accused men, i.e. about 20% of the 354 cases.

matters which were closed, the paternity claim, if suit had been brought, would probably have been dismissed. On account of observations made by me concerning the reasons for discontinuing the investigation in the closed matters, I have estimated that the paternity claim, if brought to court, would have been dismissed in, at any rate, some six of these cases. If this figure is accepted, then, depending on the number of claims since dismissed among those still pending at the time of the follow-up, the number of dismissed claims (or claims likely to have been dismissed if the investigation had not been discontinued) would amount to between 19 and 29. As regards this material, too, the correspondence is surprisingly good between the number of dismissed paternity claims and the number of those where the claim should have been dismissed according to calculations based on blood-test results.

Even if, consequently, the courts have been fairly successful in dismissing the paternity claims in approximately the correct *number* of cases, the possibility of an erroneous decision in a particular case cannot, of course, be excluded. In an attempt to obtain a clearer idea of the realities in this respect, the investigations described above will be supplemented with a quantitative analysis in the next section concerning the question which factors may actually have influenced the decisions.

VI. A QUANTITATIVE ANALYSIS OF DECIDED CASES CONCERNING THE ASCERTAINMENT OF PATERNITY

1. The quantitative analysis to be presented below is a so-called AID (Automatic Interaction Detector) analysis.[36] This constitutes an unprejudiced investigation of statistical correlations between, on the one hand, the result of the case (success or failure of the paternity claim) as the dependent variable, and on the other, as independent variables or predictors, a number of factors and circumstances registered while the collected material was being studied. Such a method of investigation may reveal some "unarticulated" grounds for the decision, namely if, through the investigation, significant correlations are shown to exist between the results of the cases and factors whose importance in this respect cannot be detected by means of ordinary methods of case law analysis.[37]

[36] On AID analysis, see in particular Sonquist & Morgan, *The Detection of Interaction Effects*, 7th printing, Ann Arbor 1970.
[37] As to the feasibility of using the AID analysis for the study of legal proceedings, see for instance Nagel, *The Legal Process from a Behavioral Perspective*, Georgetown 1969, Saldeen, *Skadestånd vid äktenskapsskillnad* (*supra*, note 3) and Grönvall, *Straffmätning* (*Slutrapport. Samarbetsorganet för rättsväsendets informationssystem* (*SARI*), published by the Ministry of Justice (*DsJu* 1980: 9), Stockholm 1980.

An AID analysis is performed by successive or stepwise divisions of the population (the sample investigated) into two mutually exclusive subgroups (classes) according to the values of one or more of the predictors. The dichotomous splitting of the sample is determined by reference to those predictors which give the highest prediction value and would then justify the assumption that an actual correlation exists between the dependent variable and the predictors in question.

2. In order to render possible a comparison of the conditions before 1970 with those obtaining since that year, when the new rule as to the ascertainment of paternity came into force (cf. section II: 3 above), the investigation covers two samples one of which—the "old sample"—consists of first instance court decisions from the period 1960–1964 and the other—the "new sample"—is made up of first instance judgments pronounced in 1970 or later.[38]

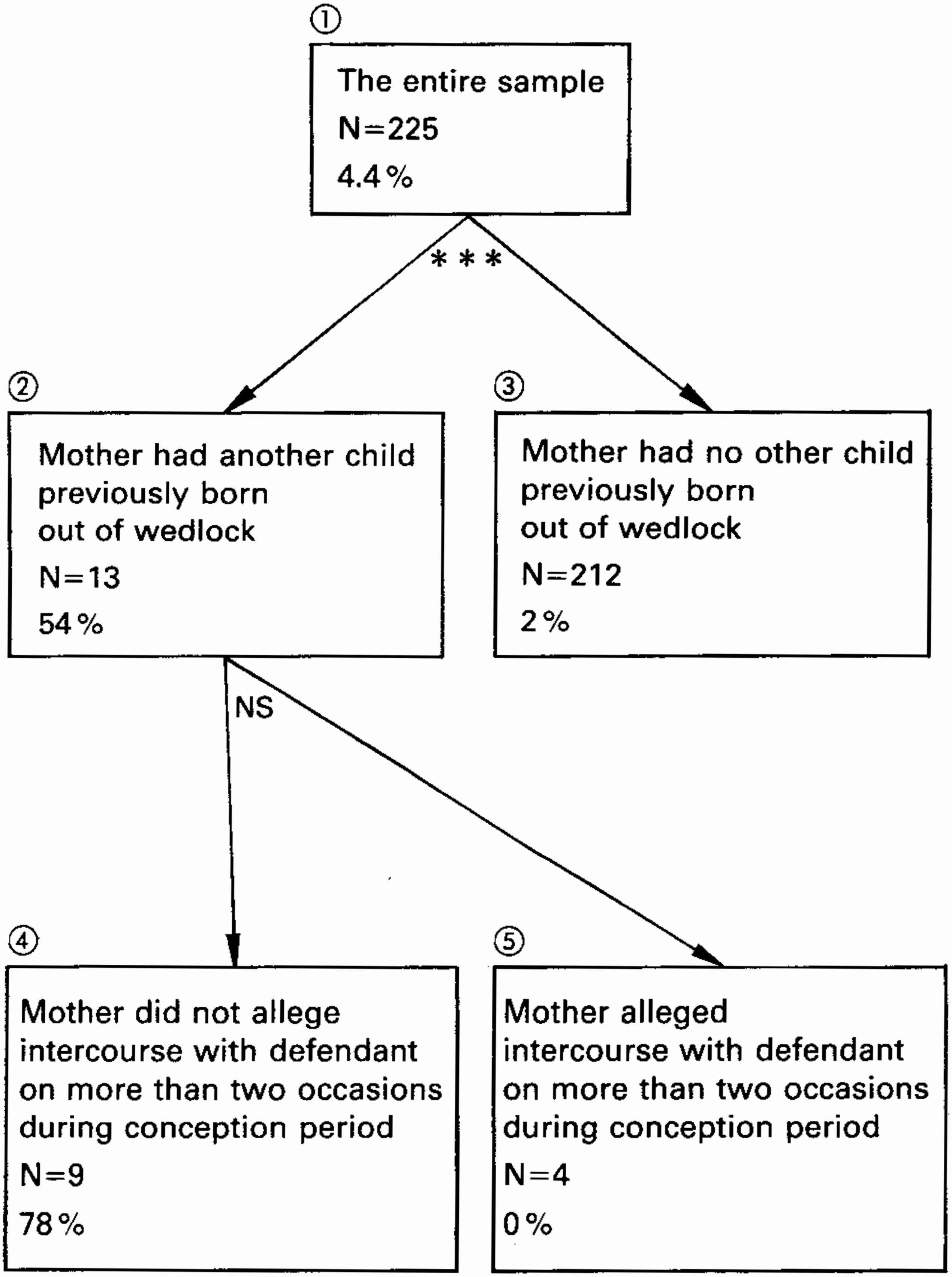
The old sample has been weighted on account of the method of selection. The new material only comprises cases where the requirement of sexual intercourse was considered proved and it has therefore been possible to concentrate the analysis of this sample on probability calculation. When the cases belonging to the old sample were decided, the negative assessment of probability was the rule in paternity suits (see section II: 3); hence a frequent ground for dismissing the claim was the fact that sexual intercourse between the mother and the defendant at the time of conception was not considered proved. Cases where intercourse was not considered proved have therefore also been included in the old sample.

A few more than 25 different predictors have been used in the analyses, such as: the number of men with whom the mother has had intercourse during the period of conception, the number of defendants in a particular case (used only as regards the new sample, cf. section II: 3), whether or not the mother already had a child born out of wedlock, whether the relation between the mother and the defendant was permanent or temporary, the frequency of intercourse, the use of contraceptives, the probability (according to the Engström-Falconer tables, see section IV: 1) of the child being conceived at the stated time having regard to its length and weight at birth, and the paternity index (used only with regard to the new sample).

The result of the analyses is displayed below in diagrams A and B in the form of so-called AID trees.

[38] The new samples comprises cases where two or more men have been sued in the same action. The number of "cases" in this material therefore equals the number of defendants and is consequently somewhat larger than the number of judgments studied.

Diagram A. *AID analysis of the old sample, the results of the paternity suits functioning as dependent variable (successful claim = 0, dismissed claim = 1).*



Each box represents a group of cases.

N=the *weighted* number of cases within each group.

The percentage indicates the extent of *dismissed* paternity claims.

The level of significance has been indicated according to the system whereby a significance (between the percentages of the groups) on the 5, 1 and 0.1 % levels is denoted by one, two or three asterisks respectively.

NS=no significant difference.

R^2 (the prediction value)=48 %.

Diagram A shows that the first split of the sample was made with regard to the question whether the mother already had a child born out of wedlock or not. It will be seen that the paternity claim was dismissed in 54 % of the cases where the child in question in the suit was not the mother's first child out of wedlock (group 2). Where neither the judgment nor the material in the file showed that the mother already had an illegitimate child, the frequency of dismissed claims only amounted to 2 % (group 3).

The cases in group 2 have then been partitioned with reference to the frequency of sexual intercourse. In the cases where the mother alleged intercourse with the defendant on many occasions (three or more), the paternity claim was not dismissed in a single case while the frequency of dismissed claims amounted to no less than 78 % among the cases where the mother did not allege intercourse on more than two occasions with the defendant during the conception period (group 4).[39]

The prediction value (R^2) in this analysis is 0.48. In other words this obviously means that an attempt made before 1970 to predict the outcome of a number of paternity suits would have been fairly successful with the sole aid of information as to whether or not the mother already had an illegitimate child.

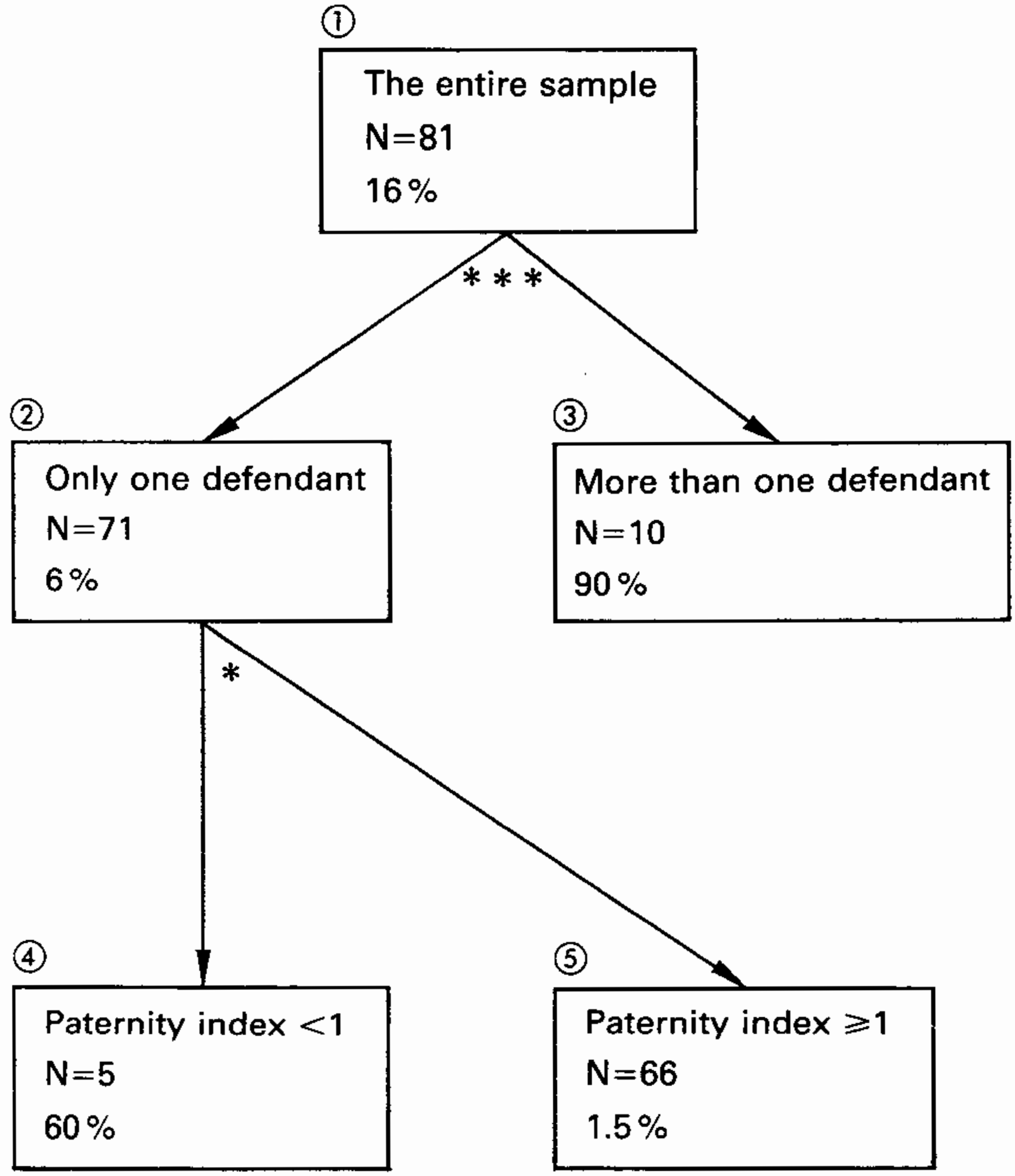
Diagram B shows that the first split in the analysis of the new sample was made, as is natural, with reference to the question whether only one or several men had been sued. Where there was only one defendant, the frequency of dismissed claims amounted to a mere 6 % as against 90 % in the cases with several defendants. The difference between the percentages is highly significant.

Otherwise only one significant correlation was obtained in the course of the analysis, namely between the outcome in one-man cases and the pater-

[39] A significance analysis has been carried out whereby the probability was treated in accordance with the hypergeometric distribution (Fisher's exact test). It shows that there is a highly significant difference between groups 2 and 3 as regards the frequency of dismissed claims even after taking account of the possibility of an entirely arbitrary division of the sample into two groups in accordance with some predictor (the so-called problems of significance *en masse*).

It is true that the difference as regards the frequency of dismissed claims between groups 4 and 5 is significant according to conventional methods of evaluation, but it is not significant if the problem of significance *en masse* is taken into account.

Diagram B. *AID analysis of the new sample, the results of the paternity suits functioning as dependent variable (successful claim = 0, dismissed claim = 1).*



Each box represents a group of cases.

N = the number of cases within each group.

The percentage indicates the extent of *dismissed* paternity claims

The level of significance has been indicated according to the system whereby a significance (between the percentages of the groups) on the 5, 1 and 0.1 % levels is denoted by one, two or three asterisks respectively.

R^2 (the prediction value) = 72 %.

nity index. If the paternity index of the defendant was less than 1, the frequency of dismissed claims amounted to 60% as against only 1.5% where the paternity index of the defendant was 1 or more.

Do the results presented above warrant the conclusion that judgments which are in fact erroneous are pronounced in this field?[40] Yes, possibly, as far as the old sample is concerned. The factor which, in the analysis of this material, revealed itself as having the strongest correlation with the outcome of the case was the mother's previous fertility out of wedlock. If this factor actually was of importance in the determination of the cases, it probably was so by influencing the assessment of the mother's credibility. That this factor should have any part to play in discriminating between fathers and non-fathers is not obvious. It may be mentioned that I have myself made an attempt, with the aid of a discriminative analysis, to study the question how various factors discriminate between fathers and non-fathers.[41] According to this analysis the factor in question had no such capacity at all. If, in fact, the question whether or not the mother already had illegitimate children was of immediate importance for the result of the action in some of the cases belonging to the old sample, then there is a risk that the decisions were not always correct. Further support for such suspicions is provided by an investigation of the paternity indices of the defendants carried out by me. When deciding the cases that form part of the sample in question, the courts did not have access to information concerning paternity indices. For my account the State Institute for Blood Group Serology has, however, afterwards calculated the paternity index in each of the various cases. If the indices are compared with the outcome of the suits, the low paternity indices will by no means be found to be concentrated among the cases of dismissed paternity claims. On the contrary, the indices are distributed over the entire scale. It may be of special interest to mention both that the paternity claim was successful in all the cases where the index was under 1 and that there was a paternity index of no less than 891 in one case where the claim was dismissed.[42]

[40] The possibility cannot, of course, be excluded that factors other than those which, in these analyses, have affected the results of the cases may, in practice, have been of importance in determining the paternity question and yet were not noticed because of the limited sizes of the samples studied.

[41] No very firm conclusions can, however, be drawn from the discrimination analysis on account, *inter alia*, of the difficulty of defining the group of *fathers* in the analysis. A defendant was regarded as father in cases where he had admitted the paternity claim (no information of the paternity index was then given) and men excluded on account of the blood test were regarded as non-fathers.

[42] No criticism of the courts is implied even if it may be assumed, accordingly, that the judgments in some cases are erroneous in fact. The courts may nevertheless have acted in full accordance with the legislation then in force.

VII. CONCLUDING REMARKS

Intensified interdisciplinary research involving the legal sciences is in my opinion urgently needed. If traditional academic research is allowed to retain its dominating position as far as the legal disciplines are concerned, important fields of research will be left uncharted.

In this essay I have endeavoured to give an outline of the work so far carried out in Sweden in the field of jurimetrics. I also hope in some measure to have succeeded in demonstrating that in certain cases a jurimetrical method may constitute an important complement to the traditional types of legal research.[43]

It is true that, so far, the number of completed jurimetrical research projects is not very large in Sweden. There is no doubt, however, that jurimetrics is a science which has come to stay and that it will steadily grow stronger. Generally, the development towards an increased element of interdisciplinary research cannot be said to have taken place at a particularly fast rate in Sweden as far as the legal disciplines are concerned. But this is hardly due to a lack of interest in such research. Instead, a probable reason of some importance is the fact that legal scientists rarely possess the necessary knowledge of other sciences, such as statistics. When this obstacle has been removed, e.g. through the arrangement of suitable instruction in interdisciplinary methods of investigation, jurimetrical research is bound to gather speed;[44] I am confident that the recruitment of creative young legal graduates for studies of this type will then be no problem.

[43] In addition to the examples of Swedish jurimetrical research referred to above in this essay, mention may be made of a large research project carried out under the leadership of Professor Anders Agell of the University of Uppsala under the title of "Maintenance and Social Benefits." In this project statistical analysis was used to determine, for instance, to what extent maintenance under family law was actually paid and what factors of a social and economic nature in reality influenced the extent of payment. On this, see Agell, "Underhåll och socialförmån. En forskningsrapport" in Government bill 1978/79:12 concerning "Maintenance Payments to Children and Divorced Spouses, etc.", pp. 312 ff.

[44] On jurimetrics in the education in the U.S.A. see, for instance, 16 *Jurimetrics Journal* 1975, pp. 71 ff.