Chapter 2
Communicating Scientific Findings in Court

H.J. Walls, Whither Forensic Science?*
6 Medicine, Science and Law 183 (1966)

[C]ommunication from science to law, which was never easy, is being made more difficult by [a] developing trend towards scientific results being expressed as probabilities — not just as something that might be so, but as something that has a definite numerically expressible chance of being so. The law, of course, wants yes or no, black or white, this or not this. In fact, . . . I have sometimes thought that it looks on "probability" as a dirty word. . . .

[A]ll scientific conclusions are really matters of probability. Sometimes, of course, this is so near 1 (that is, certainty) that it is for all practical purposes indistinguishable from certainty, and the residuum of "reasonable doubt" is vanishingly small. The principle, however, remains valid. For example, nothing is more conclusive than fingerprint evidence, but there is no prescriptive law of nature that prohibits two fingerprints from being identical. There is merely a descriptive one that two never *are* identical. That, of course, is quite easily explained: the number of possible different fingerprint patterns is large that there aren't enough fingers in the whole world over many generations to give a reasonable outside chance of two identical ones turning up.

We have indeed already seen the thin edge of the wedge go in. Courts accept evidence about glass fragments in which all the scientific witness can say is that they are indistinguishable to within certain limits of accuracy, and the odds against — that is, the probability of — that happening by chance are so and so.

There is some very interesting work going on now on the characterisation of human head hair by means of the neutron activation analysis of the trace elements in it. [R]ather bold claims were made some years ago across the Atlantic that in this way a hair could practically be tied to the head from which it came. The present, much more systematic, work has shown that these claims were undoubtedly premature and over-stated, but that considerable differences between hairs from different heads do undoubtedly occur. We are not yet ready to use the results of this work routinely in evidence, but when we are they will be meaningful only if they are given as statistical probabilities. Some quite sophisticated statistical mathematics have been developed in connection with this work, and its use will enable us to give precise estimates of probability instead of, at present, vague statements such as "similar to," "could have come from the same head" and so on. And it would obviously be quite wrong not to be precise instead of vague if the known facts make that possible.

---

*This excerpt from the presidential address of Dr. H.J. Walls to the British Academy of Forensic Sciences is reprinted by permission of *Medicine, Science and the Law*.

Indeed there is really no reason why in certain fields that sort of evidence should not now be used more than it is. The distribution of blood groups within the various blood-group systems which we can now determine on dried blood stains is known, at least for the population of this country. . . . Suppose . . . that a specimen of blood is grouped according to four independent systems, and that it belongs to the commonest group in each, and . . . that each of these groups occurs in half the population. Half the population is a large number of people, but when four independent systems are in question, . . . the blood could only have come from half of half of half of half of the population — that is, one-sixteenth. . . . If we could use eight systems, on the same assumption [of independence] we would have come down to one-256th part of the population. And if the groups to which the blood belongs happen to be among the rarer ones, it is quite on the cards that we can say that only one person in several thousand has this combination of groups. As a matter of fact, we do say that sort of thing now when the opportunity to do so arises. But there is no reason why we should not carry it a little farther. It should not be impossible in some cases to make an estimate of the number of persons from whom, on other evidence, the blood might have come. Suppose [there] were 100 [such people]. The important question then is: if the bloodstain and the [accused] are of the same rare combination of groups, what is the probability of more than one person in that 100 having it? If . . . one person in 5,000 in the population as a whole shows that particular combination, then . . . the probability of two people out of our 100 showing it is 1/2,500 — that is, the odds against the event are 2,500 to one — and the probability of more than two people out of the 100 having it is quite vanishingly small. And, obviously, the smaller the number of persons from whom the blood *might* have come, the smaller the corresponding probability. If instead of 100 it was, say, twenty, then the odds against more than one person in that twenty having the same combination of groups are over 60,000 to one. Does that sort of figure constitute proof "beyond all reasonable doubt?"

We as scientists often wonder indeed just what "beyond all reasonable doubt" really means. Can we give it a quantitative connotation? . . . [L]aw and science would at least make a more harmonious marriage if we could put some sort of figure on "beyond reasonable doubt." Does it mean a probability of .99, or .999 or .999999 or something even higher? Should it be a higher probability in a trial for murder than in one for petty larceny? I leave the thought with you.

NOTES

1. *Hair individualization probabilities*. Dr. Walls' prediction that new "sophisticated statistical mathematics" will yield "precise estimates of probabilities" derived from neutron activation analysis of human hair has yet to be realized. See Rita Cornelis, Truth has Many Facets: The Neutron Activation Analysis Story, 20

J. Forensic Sci. Soc'y 93, 95 (1980); Dennis Karjala, Comment, The Evidentiary Uses of Neutron Activation Analysis, 59 Cal. L. Rev. 997 (1971).

A form of DNA testing also can be performed on some hairs. The mitochondrial DNA sequencing that is done on hair is much less revealing than the DNA tests that can be done with materials that contain larger amounts of DNA, but matches among unrelated individuals are uncommon. With appropriate sampling, the probability of particular DNA sequences among unrelated individuals can be estimated.

Microscopic comparison also is useful in discerning whether hair fibers come from the same individual, and several cases mentioned later in this chapter (*DiGiacomo*, *Massey*, *Boyd*, and *Carlson*) concern probabilities based on microscopic comparisons of hair samples. A substantial fraction of suspects who are found to match crime-scene samples of hairs as determined by such comparisons have been excluded on the basis of DNA testing. One study of human hairs submitted to the FBI Laboratory for analysis between 1996 and 2000 found that of 170 hair examinations, there were 80 microscopic associations, and that of these 80, nine (11%) were excluded by DNA. M.M. Houck & B. Budowle, Correlation of Microscopic and Mitochondrial DNA Hair Comparisons, 47 J. Forensic Sci. 964 (2002). Does this mean that 11% or so of hair microanalysts are mendacious or incompetent?

2. *1/2500 as the probability of innocence*. Dr. Walls notes that the probability of finding two or more individuals having an incriminating trait out of 100 persons selected at random from a large population in which one out of every five thousand people has this trait is 1/2500. Cf. David Finney, Probabilities Based on Circumstantial Evidence, 72 J. Am. Stat. Ass'n 316 (1977). He speaks of odds of 2500 to one in favor of guilt because he presupposes that the other non-scientific evidence in the case establishes that there are only 100 individuals who could be guilty. The mechanics of the calculation that yields the probability of 1/2500 are described in William Fairley & Frederick Mosteller, A Conversation About Collins, 41 U. Chi. L. Rev. 242 (1974); cf. David J. Balding & Peter Donnelly, Inference in Forensic Identification, 157 J. Royal Stat. Soc'y A 21 (1994); R.V. Lenth, On Identification by Probability, 26 J. Forensic Sci. Soc'y 197 (1986). For those who enjoy mathematical puzzles, the logic of the computation is as follows:

> Let T stand for the incriminating trait (the blood groups). The frequency of T is $F(T) = 1/5000$. In other words, in a large population, T occurs in about one person in 5,000. Hence, the probability of T in an individual randomly selected from this population is $p = F(T) = 1/5000$. Dr. Walls imagines that a number $n = 100$ suspects are drawn at random (or without regard to their blood types) from this population, and he reports that the chance of two or more suspects possessing T is 1/2,500.
>
> If we let x designate the number of suspects with T, then x could equal either 0, 1, 2, ..., 100, and the claim is that $\Pr(x \geq 2) \approx 1/2500$. (The symbol "$\geq$" means "is greater than or equal to," and "$\Pr(x)$" stands for "probability of x.") To have $x \geq 2$, we could have either x=2, x=3,

and so on, through x=100. Since these are mutually exclusive events, the probability of this joint event is the sum of the probabilities of each:

$$\Pr(x \geq 2) = \Pr(2) + \Pr(3) + ... + \Pr(100). \quad (1)$$

It would be tedious to compute these directly, but we know that the probability that either x=0, x=1, x=2, ..., x=100 is 1. In other words, the probability that some number between 0 and 100 of the 100 suspects have *T* is 1:

$$\Pr(0) + \Pr(1) + \Pr(2) + ... + \Pr(100) = 1. \quad (2)$$

Comparing (1) and (2),

$$\Pr(x \geq 2) = 1 - \Pr(0) - \Pr(1). \quad (3)$$

So all we need do is find Pr(0) and Pr(1) and subtract their sum from 1. The probability of drawing no suspects with *T* is easy to find. The chance of not-*T* on the first draw is the fraction of people in the population who lack trait *T*. This chance is 1 minus the fraction with *T*, or 1 – F = 1 – 1/5000. In a very large population, the chance of not-*T* on the second through the 100th draws is the same. Since each draw is independent, the overall probability is the following product:

$$\Pr(0) = (1 - F)^{100} = (1 - 1/5000)^{100}. \quad (4)$$

The binomial expansion of (4) — which we can just accept on faith or look up in a high school text — reveals that for small F, like 1/5,000), we need not perform the multiplication 100 times, but can approximate the result as follows:

$$\Pr(0) \approx 1 - 100/5000 = 1 - 1/50. \quad (5)$$

P(1) is slightly more complicated in that while there is only one way to draw 100 not-*T*s, there are 100 ways to draw exactly one *T* in a 100 draws. (We could draw a *T* followed by 99 not-*T*s, a not-*T* followed by a *T* followed by 98 not-*T*s, and so on.) Fortunately, the probability of each of these sequences is the same, so we just need to find one and multiply it by 100 to find the probability of 1 *T*, without regard to which of the 100 it is. Now, the probability of 1 *T* followed by 99 not-*T*s is the chance of a *T* on the first draw times the chance of 99 not-*T*s:

$$F(1-F)^{99} = (1/5{,}000)(1 - 1/5{,}000)^{99}$$
$$\approx (1/5000)(1 - 99/5000) \approx (1/5000)(1 - 1/50).$$

Hence,

$$\Pr(1) \approx 100(1/5000)(1 - 1/50) = (1/50)(1 - 1/50). \quad (6)$$

We are practically done. Try substituting (5) and (6) into (3) to see whether $\Pr(x \geq 2) \approx$ 1/2,500, as Dr. Walls claims.

3. One might think that the computation of 1/2500 in note 2 could not possibly be discussed in a courtroom or by a court. In *People v. Collins*, 438 P. 2d 33 (Cal. 1968), however, the California Supreme Court introduced just such a calculation in an opinion that often is cited by parties seeking to exclude “probability evidence." The opinion is set forth below. What numbers are analogous to the quantities $F(T) = 1/5000$, $n = 100$, and $\Pr(x \geq 2) \approx 1/2500$? What reasons did the court offer for condemning the mathematician's testimony? Do these apply to Dr. Wall's proposed testimony?

People v. Collins

438 P. 2d 33 (Cal. 1968)

SULLIVAN, Justice.

We deal here with the novel question whether evidence of mathematical probability has been properly introduced and used by the prosecution in a criminal case. While we discern no inherent incompatibility between the disciplines of law and mathematics and intend no general disapproval or disparagement of the latter as an auxiliary in the fact-finding processes of the former, we cannot uphold the technique employed in the instant case. As we explain in detail infra, the testimony as to mathematical probability infected the case with fatal error and distorted the jury's traditional role of determining guilt or innocence according to long-settled rules. Mathematics, a veritable sorcerer in our computerized society, while assisting the trier of fact in the search for truth, must not cast a spell over him. We conclude that on the record before us defendant should not have had his guilt determined by the odds and that he is entitled to a new trial. We reverse the judgment.

A jury found defendant Malcolm Ricardo Collins and his wife defendant Janet Louise Collins guilty of second degree robbery. Malcolm appeals from the judgment of conviction. Janet has not appealed.

On June 18, 1964, about 11:30 a.m. Mrs. Juanita Brooks, who had been shopping, was walking home along an alley in the San Pedro area of the City of Los Angeles. She was pulling behind her a wicker basket carryall containing groceries and had her purse on top of the packages. She was using a cane. As she stooped down to pick up an empty carton, she was suddenly pushed to the ground by a person whom she neither saw nor heard approach. She was stunned by the fall and felt some pain. She managed to look up and saw a young woman running from the scene. According to Mrs. Brooks the latter appeared to weigh about 145 pounds, was wearing "something dark," and had hair "between a dark blond and a light blond," but lighter than the color of defendant Janet Collins" hair as it appeared at trial. Immediately after the incident, Mrs. Brooks discovered that her purse, containing between $35 and $40, was missing.

About the same time as the robbery, John Bass, who lived on the street at the end of the alley, was in front of his house watering his lawn. His attention was attracted by "a lot of crying and screaming" coming from the alley. As he looked in that direction, he saw a woman run out of the alley and enter a yellow automobile parked across the street from him. He was unable to give the make of the car. The car started off immediately and pulled wide around another parked vehicle so that in the narrow street it passed within six feet of Bass. The latter then saw that it was being driven by a male Negro, wearing a mustache and beard. At the trial Bass identified defendant as the driver of the yellow automobile. However, an attempt was made to impeach his identification by his admission that at the preliminary hearing he testified to an uncertain identification at the police lineup shortly after the attack on Mrs. Brooks, when defendant was beardless.

In his testimony Bass described the woman who ran from the alley as a Caucasian, slightly over five feet tall, of ordinary build, with her hair in a dark blond ponytail, and wearing dark clothing. He further testified that her ponytail was "just like" one which Janet had in a police photograph taken on June 22, 1964.

On the day of the robbery, Janet was employed as a housemaid in San Pedro. Her employer testified that she had arrived for work at 8:50 a.m. and that defendant had picked her up in a light yellow car[1] about 11:30 a.m. On that day, according to the witness, Janet was wearing her hair in a blonde ponytail but lighter in color than it appeared at trial.[2]

There was evidence from which it could be inferred that defendants had ample time do drive from Janet's place of employment and participate in the robbery. Defendants testified, however, that they went directly from her employer's house to the home of friends, where they remained for several hours.

In the morning of June 22, Los Angeles Police Officer Kinsey, who was investigating the robbery, went to defendants' home. He saw a yellow Lincoln automobile with an off-white top in front of the house. He talked with defendants. Janet, whose hair appeared to be a dark blonde, was wearing it in a ponytail. Malcolm did not have a beard. The officer explained to them that he was investigating a robbery specifying the time and place; that the victim had been knocked down and her purse snatched; and that the person responsible was a female Caucasian with blonde hair in a ponytail who had left the scene in a yellow car driven by a male Negro. He requested that defendants accompany him to the police station at San Pedro and they did so. There, in response to police inquiries as to defendants' activities at the time of the robbery, Janet stated, according to Officer Kinsey, that her husband had picked her up at her place of employment at 1 p.m. and and that they had then visited at the home of friends in Los Angeles. Malcolm confirmed this. Defendants were detained for an hour or two, were

---

[1]Other witnesses variously described the car as yellow, as yellow with an off-white top, and yellow with an egg-shell white top. The car was also described as being medium to large in size. Defendant drove a car at or near the times in question which was a Lincoln with a yellow body and a white top.

[2]There are inferences which may be drawn from the evidence that Janet attempted to alter the appearance of her hair after June 18. Janet denies that she cut, colored or bleached her hair at any time after June 18, and a number of witnesses supported her testimony.

photographed but not booked, and were eventually released and driven home by the police.

Late in the afternoon of the same day, Officer Kinsey, while driving home from work in his own car, saw defendants riding in their yellow Lincoln. Although the transcript fails to disclose what prompted such action Kinsey proceeded to place them under surveillance and eventually followed them home. He called for assistance and arranged to meet other police officers in the vicinity of defendants' home. Kinsey took a position in the rear of the premises. The other officers, who were in uniform and had arrived in a marked police car, approached defendants' front door. As they did so, Kinsey saw defendant Malcolm Collins run out the back door toward a rear fence and disappear behind a tree. Meanwhile the other officers emerged with Janet Collins whom they had placed under arrest. A search was made for Malcolm who was found in a closet of a neighboring home and also arrested. Defendants were again taken to the police station, were kept in custody for 48 hours, and were again released without any charges being made against them.

Officer Kinsey interrogated defendants separately on June 23 while they were in custody and testified to their statements over defense counsel's objections based on the decision in *Escobedo* and our first decision in *Dorado*.[3] According to the officer, Malcolm stated that he sometimes wore a beard but that he did not wear a beard on June 18 (the day of the robbery), having shaved it off on June 2, 1964.5 He also explained two receipts for traffic fines totalling $35 paid on June 19, which receipts had been found on his person, by saying that he used funds won in a gambling game at a labor hall. Janet, on the other hand, said that the $35 used to pay the fines had come from her earnings.

On July 9, 1964, defendants were again arrested and were booked for the first time. While they were in custody and awaiting the preliminary hearing, Janet requested to talk with Officer Kinsey. There followed a lengthy conversation during the first part of which Malcolm was not present. During this time Janet expressed concern about defendant and inquired as to what the outcome would be If it appeared that she committed the crime and Malcolm knew nothing about it. In general she indicated a wish that defendant be released from any charges because of his prior criminal record and that if someone must be held responsible, she alone would bear the guilt. The officer told her that no assurances could be given, that if she wanted to admit responsibility disposition of the matter would be in the hands of the court and that if she committed the crime and defendant knew nothing about it the only way she could help him would be by telling the truth. Defendant was then brought into the room and participated in the rest of the conversation. The officer asked to hear defendant's version of the matter, saying that he believed

---

[3][Escobedo v. Illinois, 378 U.S. 478 (1964), and People v. Dorado, 62 Cal. 2d 338, 42 Cal. Rptr. 169, 398 P. 2d 361 (1965), concern the admissibility of statements obtained in violation of a suspect's right to counsel.]

defendant was at the scene. However, neither Janet nor defendant confessed or expressly made damaging admissions although constantly urged by the investigating officer to make truthful statements. On several occasions defendant denied that he knew what had gone on in the alley. On the other hand, the whole tone of the conversation evidenced a strong consciousness of guilt on the part of both defendants who appeared to be seeking the most advantageous way out. Over defense counsel's same objections based on *Escobedo* and *Dorado*, some parts of the foregoing conversation were testified to by Officer Kinsey and in addition a tape recording of the entire conversation was introduced in evidence and played to the jury.

At the seven-day trial the prosecution experienced some difficulty in establishing the identities of the perpetrators of the crime. The victim could not identify Janet and had never seen defendant. The identification by the witness Bass, who observed the girl run out of the alley and get into the automobile, was incomplete as to Janet and may have been weakened as to defendant. There was also evidence, introduced by the defense, that Janet had worn light-colored clothing on the day in question, but both the victim and Bass testified that the girl they observed had worn dark clothing.

In an apparent attempt to bolster the identifications, the prosecutor called an instructor of mathematics at a state college. Through this witness he sought to establish that, assuming the robbery was committed by a Caucasian woman with a blond ponytail who left the scene accompanied by a Negro with a beard and mustache, there was an overwhelming probability that the crime was committed by any couple answering such distinctive characteristics. The witness testified, in substance, to the "product rule," which states that the probability of the joint occurrence of a number of mutually independent events is equal to the product of the individual probabilities that each of the events will occur.[8] Without presenting any statistical evidence whatsoever in support of the probabilities for the factors selected, the prosecutor then proceeded to have the witness assume probability factors for the various characteristics which he deemed to be shared by the guilty couple and all other couples answering to such distinctive characteristics.[10]

---

[8]In the example employed for illustrative purposes at the trial, the probability of rolling one die and coming up with a "2" is 1/6, that is, any one of the six faces of a die has one chance in six of landing face up on any particular roll. The probability of rolling two "2"s' in succession is 1/6 x 1/6, or 1/36, that is, on only one occasion out of 36 double rolls (or the roll of two dice), will the selected number land face up on each roll or die.

[10]Although the prosecutor insisted that the factors he used were only for illustrative purposes — to demonstrate how the probability of the occurrence of mutually independent factors affected the probability that they would occur together -- he nevertheless attempted to use factors which he personally related to the distinctive characteristics of defendants. In his argument to the jury he invited the jurors to apply their own factors, and asked defense counsel to suggest what the latter

Applying the product rule to his own factors the prosecutor arrived at a probability that there was but one chance in 12 million that any couple possessed the distinctive characteristics of the defendants. Accordingly, under this theory, it was to be inferred that there could be but one chance in 12 million that defendants were innocent and that another equally distinctive couple actually committed the robbery. Expanding on what he had thus purported to suggest as a hypothesis, the prosecutor offered the completely unfounded and improper testimonial assertion that, in his opinion, the factors he had assigned were "conservative estimates" and that, in reality "the chances of anyone else besides these defendants being there, * * * having every similarity, * * * is somewhat like one in a billion."

Objections were timely made to the mathematician's testimony on the grounds that it was immaterial, that it invaded the province of the jury, and that it was based on unfounded assumptions. The objections were "temporarily overruled" and the evidence admitted subject to a motion to strike. When that motion was made at the conclusion of the direct examination, the court denied it, stating that the testimony had been received only for the "purpose of illustrating the mathematical probabilities of various matters, the possibilities for them occurring or re-occurring."

Both defendants took the stand in their own behalf. They denied and knowledge of or participation in the crime and stated that after Malcolm called for Janet at her employer's house they went directly to a friend's house in Los Angeles where they remained for some time. According to this testimony defendants were not near the scene of the robbery when it occurred. Defendant's friends testified to a visit by them "in the middle of June" although she could not recall the precise date. Janet further testified that certain inducements were held out to her during the July 9 interrogation on condition that she confess her participation.

---

would deem as reasonable. The prosecutor himself proposed the individual probabilities set out in the table below. Although the transcript of the examination of the mathematics instructor and the information volunteered by the prosecutor at that time create some uncertainty as to precisely which of the characteristics the prosecutor assigned to the individual probabilities, he restated in his argument to the jury that they should be as follows:

Characteristic	*Individual Probability*
A. Partly yellow automobile	1/10
B. Man with mustache	1/4
C. Girl with ponytail	1/10
D. Girl with blond hair	1/3
E. Negro man with beard	1/10
F. Interracial couple in car	1/1000

In his brief on appeal defendant agrees that the foregoing appeared on a table presented in the trial court.

Defendant [contends] that the introduction of evidence pertaining to the mathematical theory of probability and the use of the same by the prosecution during the trial was error prejudicial to defendant. . . .

As we shall explain, the prosecution's introduction and use of mathematical probability statistics injected two fundamental prejudicial errors into the case: (1) The testimony itself lacked an adequate foundation both in evidence and in statistical theory; and (2) the testimony and the manner in which the prosecution used it distracted the jury from its proper and requisite function of weighing the evidence on the issue of guilt, encouraged the jurors to rely upon an engaging but logically irrelevant expert demonstration, foreclosed the possibility of an effective defense by an attorney apparently unschooled in mathematical refinements, and placed the jurors and defense counsel at a disadvantage in sifting relevant fact from inapplicable theory.

We initially consider the defects in the testimony itself. As we have indicated, the specific technique presented through the mathematician's testimony and advanced by the prosecutor to measure the probabilities in question suffered from two basic and pervasive defects — an inadequate evidentiary foundation and an inadequate proof of statistical independence. First, as to the foundation requirement, we find the record devoid of any evidence relating to any of the six individual probability factors used by the prosecutor and ascribed by him to the six characteristics as we have set them out . . . . To put it another way, the prosecution produced no evidence whatsoever showing, or from which it could be in any way inferred, that only one out of every ten cars which might have been at the scene of the robbery was partly yellow, that only one out of every four men who might have been there wore a mustache, that only one out of every ten girls who might have been there wore a ponytail, or that any of the other individual probability factors listed were even roughly accurate.

The bare, inescapable fact is that the prosecution made no attempt to offer any such evidence. Instead, through leading questions having perfunctorily elicited from the witness the response that the latter could not assign a probability factor for the characteristics involved, the prosecutor himself suggested what the various probabilities should be and these became the basis of the witness' testimony. It is a curious circumstance of this adventure in proof that the prosecutor not only made his own assertions of these factors in the hope that they were "conservative" but also in later argument to the jury invited the jurors to substitute their "estimates" should they wish to do so. We can hardly conceive of a more fatal gap in the prosecution's scheme of proof. A foundation for the admissibility of the witness' testimony was never even attempted to be laid, let alone established. His testimony was neither made to rest on his own testimonial knowledge nor presented by proper hypothetical questions based upon valid data in the record. . . . In [State v. Sneed, 76 N.M. 349, 414 P.2d 858, 862 (1966)] the court reversed a conviction based on probabilistic evidence, stating: "We hold that mathematical odds are not admissible as evidence to identify a defendant in a criminal proceeding so long as the odds are based on estimates, the validity of which have (sic) not been demonstrated." (Italics added.).

But, as we have indicated, there was another glaring defect in the prosecution's technique, namely an inadequate proof of the statistical independence of the six factors. No proof was presented that the characteristics selected were mutually independent, even though the witness himself acknowledged that such condition was essential to the proper application of the "product rule" or "multiplication rule." (See Note, supra, Duke L.J. 665, 669-670, fn. 25.) To the extent that the traits or characteristics were not mutually independent (e.g. Negroes with beards and men with mustaches obviously represent overlapping categories), the "product rule" would inevitably yield a wholly erroneous and exaggerated result even if all of the individual components had been determined with precision. (Siegel, Nonparametric Statistics for the Behavioral Sciences (1956) 19; see generally Harmon, Modern Factor Analysis (1960).)

In the instant case, therefore, because of the aforementioned two defects — the inadequate evidentiary foundation and the inadequate proof of statistical independence — the technique employed by the prosecutor could only lead to wild conjecture without demonstrated relevancy to the issues presented. It acquired no redeeming quality from the prosecutor's statement that it was being used only "for illustrative purposes" since, as we shall point out, the prosecutor's subsequent utilization of the mathematical testimony was not confined within such limits.

We now turn to the second fundamental error caused by the probability testimony. Quite apart from our foregoing objections to the specific technique employed by the prosecution to estimate the probability in question, we think that the entire enterprise upon which the prosecution embarked, and which was directed to the objective of measuring the likelihood of a random couple possessing the characteristics allegedly distinguishing the robbers, was gravely misguided. At best, it might yield an estimate as to how infrequently bearded Negroes drive yellow cars in the company of blonde females with ponytails.

The prosecution's approach, however, could furnish the jury with absolutely no guidance on the crucial issue: Of the admittedly few such couples, which one, if any, was guilty of committing this robbery? Probability theory necessarily remains silent on that question, since no mathematical equation can prove beyond a reasonable doubt (1) that the guilty couple In fact possessed the characteristics described by the People's witnesses, or even (2) that only one couple possessing those distinctive characteristics could be found in the entire Los Angeles area.

As to the first inherent failing we observe that the prosecution's theory of probability rested on the assumption that the witnesses called by the People had conclusively established that the guilty couple possessed the precise characteristics relied upon by the prosecution. But no mathematical formula could ever establish beyond a reasonable doubt that the prosecution's witnesses correctly observed and accurately described the distinctive features which were employed to link defendants to the crime. . . . Conceivably, for example, the guilty couple might have included a light-skinned Negress with bleached hair rather than a Caucasian blonde; or the driver of the car might have been wearing a false beard as a disguise; or the prosecution's witnesses might simply have been unreliable.

The foregoing risks of error permeate the prosecution's circumstantial case. Traditionally, the jury weighs such risks in evaluating the credibility and probative value of trial testimony, but the likelihood of human error or of falsification obviously cannot be quantified; that likelihood must therefore be excluded from any effort to assign a number to the probability of guilt or innocence. Confronted with an equation which purports to yield a numerical index of probable guilt, few juries could resist the temptation to accord disproportionate weight to that index; only an exceptional juror, and indeed only a defense attorney schooled in mathematics, could successfully keep in mind the fact that the probability computed by the prosecution can represent, at best, the likelihood that a random couple would share the characteristics testified to by the People's witnesses — not necessarily the characteristics of the actually guilty couple.

As to the second inherent failing in the prosecution's approach, even assuming that the first failing could be discounted, the most a mathematical computation could ever yield would be a measure of the probability that a random couple would possess the distinctive features in question. In the present case, for example, the prosecution attempted to compute the probability that a random couple would include a bearded Negro, a blonde girl with a ponytail, and a partly yellow car; the prosecution urged that this probability was no more than one in 12 million. Even accepting this conclusion as arithmetically accurate, however, one still could not conclude that the Collinses were probably the guilty couple. On the contrary, as we explain in the Appendix, the prosecution's figures actually imply a likelihood of over 40 percent that the Collinses could be "duplicated" by at least One other couple who might equally have committed the San Pedro robbery. Urging that the Collinses be convicted on the basis of evidence which logically establishes no more than this seems as indefensible as arguing for the conviction of X on the ground that a witness saw either X or X's twin commit the crime.

Again, few defense attorneys, and certainly few jurors, could be expected to comprehend this basic flaw in the prosecution's analysis. Conceivably even the prosecutor erroneously believed that his equation established a high probability that no other bearded Negro in the Los Angeles area drove a yellow car accompanied by a ponytailed blonde. In any event, although his technique could demonstrate no such thing, he solemnly told the jury that he had supplied mathematical proof of guilt.

Sensing the novelty of that notion, the prosecutor told the jurors that the traditional idea of proof beyond a reasonable doubt represented "the most hackneyed, stereotyped, trite, misunderstood concept in criminal law." He sought to reconcile the jury to the risk that, under his "new math" approach to criminal jurisprudence, "on some rare occasion * * * an innocent person may be convicted." "Without taking that risk," the prosecution continued, "life would be intolerable * * * because * * * there would be immunity for the Collinses, for people who chose not to be employed to go down and push old ladies down and take their money and be immune because how could we ever be sure they are the ones who did it?"

In essence this argument of the prosecutor was calculated to persuade the jury to convict defendants whether or not they were convinced of their guilt to a moral certainty and beyond a reasonable doubt. Undoubtedly the jurors were unduly impressed by the mystique of the mathematical demonstration but were unable to assess its relevancy or value. Although we make no appraisal of the proper applications of mathematical techniques in the proof of facts, we have strong feelings that such applications, particularly in a criminal case, must be critically examined in view of the substantial unfairness to a defendant which may result from ill conceived techniques with which the trier of fact is not technically equipped to cope. . . . We feel that the technique employed in the case before us falls into the latter category.

We conclude that the court erred in admitting over defendant's objection the evidence pertaining to the mathematical theory of probability and in denying defendant's motion to strike such evidence. The case was apparently a close one. The jury began its deliberations at 2:46 p.m. on November 24, 1964, and retired for the night at 7:46 p.m.; the parties stipulated that a juror could be excused for illness and that a verdict could be reached by the remaining 11 jurors; the jury resumed deliberations the next morning at 8:40 a.m. and returned verdicts at 11:58 a.m. after five ballots had been taken. In the light of the closeness of the case, which as we have said was a circumstantial one, there is a reasonable likelihood that the result would have been more favorable to defendant if the prosecution had not urged the jury to render a probabilistic verdict. In any event, we think that under the circumstances the "trial by mathematics" so distorted the role of the jury and so disadvantaged counsel for the defense, as to constitute in itself a miscarriage of justice. After an examination of the entire cause, including the evidence, we are of the opinion that it is reasonably probable that a result more favorable to defendant would have been reached in the absence of the above error. . . . The judgment against defendant must therefore be reversed.

. . .

APPENDIX

If "P" represents the probability that a certain distinctive combination of characteristics, hereinafter designated "C," will occur jointly in a random couple, then the probability that C will not occur in a random couple is $1 - P$. Applying the product rule (see fn. 8, ante), the probability that C will occur in none of N couples chosen at random is $(1 - P)^N$, so that the probability of C occurring in at least one of N random couples is $1 - (1 - P)^N$.

Given a particular couple selected from a random set of N, the probability of C occurring in that couple (i.e., P), multiplied by the probability of C occurring in none of the remaining N – 1 couples (i.e., $(1 - P)^{N-1}$), yields the probability that C will occur in the selected couple and in no other. Thus the probability of C occurring in any particular couple, and in that couple alone, is $P(1 - P)^{N-1}$. Since this is true for each of the N couples, the probability that C will occur in precisely one of the N couples, without regard to which one, is $P(1 - P)^{N-1}$ added N times, because the probability of the occurrence of one of several mutually exclusive events is equal to the sum of the individual probabilities. Thus the probability of C occurring in exactly one of N random couples (any one, but only one) is $NP(1- P)^{N-1}$.

By subtracting the probability that C will occur in exactly one couple from the probability that C will occur in at least one couple, one obtains the probability that C will occur in more than one couple: $1 - (1 - P)^N - NP(1 - P)^{N-1}$. Dividing this difference by the probability that C will occur in at least one couple (i.e., dividing the difference by $1 - (1 - P)^N$ then yields the probability that C will occur more than once in a group of N couples in which C occurs at least once.

Turning to the case in which C represents the characteristics which distinguish a bearded Negro accompanied by a ponytailed blonde in a yellow car, the prosecution sought to establish that the probability of C occurring in a random couple was 1/12,000,000 — i.e., that P = 1/12,000,000. Treating this conclusion as accurate, it follows that, in a population of N random couples, the probability of C occurring exactly once is $N(1/12{,}000{,}000)(1 - 1/12{,}000{,}000)^{N-1}$. Subtracting this product from 1 – (1 – 1/12,000,000)N, the probability of C occurring in at least one couple, and dividing the resulting difference by $1 - (1 - 1/12{,}000{,}000)^N$, the probability that C will occur in at least one couple, yields the probability that C will occur more than once in a group of N random couples of which at least one couple (namely, the one seen by the witnesses) possesses characteristics C. In other words, the probability of another such couple in a population of N is the quotient A/B, where A designates the numerator $1 - (1 - 1/12{,}000{,}000)^N - N(1/12{,}000{,}000)(1 - 1/12{,}000{,}000)^{N-1}$, and B designates the denominator $1 - (1 - 1/12{,}000{,}000)^N$.

N, which represents the total number of all couples who might conceivably have been at the scene of the San Pedro robbery, is not determinable, a fact which suggests yet another basic difficulty with the use of probability theory in establishing identity. One of the imponderables in determining N may well be the number of N-type couples in which a single person may participate. Such considerations make it evident that N, in the area adjoining the robbery, is in excess of several million; as N assumes values of such magnitude, the quotient A/B computed as above, representing the probability of a second couple as distinctive as the one described by the prosecution's witnesses, soon exceeds 4/10. Indeed, as N approaches 12 million, this probability quotient rises to approximately 41 percent. We note parenthetically that if 1/N = P, then as N increases indefinitely, the quotient in question approaches a limit of (e – 2)/(e – 1), where "e" represents the transcendental number (approximately 2.71828) familiar in mathematics and physics.

Hence, even if we should accept the prosecution's figures without question, we would derive a probability of over 40 percent that the couple observed by the witnesses could be "duplicated" by at least one other equally distinctive interracial couple in the area, including a Negro with a beard and mustache, driving a partly yellow car in the company of a blonde with a ponytail. Thus the prosecution's computations, far from establishing beyond a reasonable doubt that the Collinses were the couple described by the prosecution's witnesses, imply a very substantial likelihood that the area contained more than one such couple, and that a couple other than the Collinses was the one observed at the scene of the robbery.

McCOMB, Justice.

I dissent. I would affirm the judgment in its entirety.

NOTES

1. *Foundation*. What exactly was the statistical evidence in *Collins*?

2. *Dependence*. The *Collins* Court asserts that "[t]o the extent that the traits or characteristics were not mutually independent . . . , the 'product rule' would inevitably yield a wholly erroneous and exaggerated result . . . ." Is this really true? Two events A and B are said to be stochastically independent if and only if $\Pr(AB) = \Pr(A) \times \Pr(B)$. If instead $\Pr(AB) < \Pr(A) \times \Pr(B)$ or if $\Pr(AB) > \Pr(A) \times \Pr(B)$, then A and B are dependent. For example, suppose that we draw two cards from a well-shuffled standard deck of 52 cards. Let A be the event that an ace is drawn first, and let B be the event that an ace also appears on the second draw. If we replace the first card and reshuffle the deck before drawing the second, then A and B are independent:

$$\Pr(AB) = \Pr(A)\,\Pr(B) = (4/52)(4/52) = 0.00592.$$

If we do not replace the first card, the events are dependent. But we still can find the probability of drawing two aces. We simply have to account for the fact that B is affected by the occurrence of A. To do so, we introduce the expression $\Pr(B|A)$ to denote "the probability of B given A." Since there is one fewer ace in the deck after the first card is drawn, the probability of a second ace given the first one is $\Pr(B|A) = 3/51$. Now we observe that the probability of A and B occurring is the probability of A occurring multiplied by the probability of B given the occurrence of A:

$$\Pr(AB) = \Pr(A)\ \Pr(B|A) = (4/52)(3/51) = 0.00452.$$

In this instance, treating A and B as if they were independent gives a number that understates how improbable the joint event AB is. Here, dependence does not exaggerate the improbability of the event; it understates it. This dependence should not bar the use of the "product rule" for unconditional probabilities by a party seeking to prove that the deck was not well shuffled.

This example suggests that *Collins* should not be read as prohibiting every joint probability computation that presumes independence. The issue in this regard is whether the departure from independence is likely to be substantial and which way it is likely to cut. In *Collins* itself, it was clear that several characteristics were likely to be significantly and positively correlated, making the independence-based computation unfair to the defendant. For example, the prosecutor in *Collins* suggested that the probability of man with a beard was 1/4, while that of man with a mustache was 1/10. If having a beard and mustache were independent, the joint probability would be the product of these two numbers, 1/40. However, if 1/5 of men with beards also have mustaches, then the joint probability is 1/20, which is twice as large. Here, the possible dependence is substantial, and failing to account for it permits the prosecution to make the joint probability seem larger than it is.

3. *Transposition fallacy*. The *Collins* court suggests that even if the problems with the foundation of the 1/12,000,000 figure were overcome, its admission would be impermissible because "the most a mathematical computation could ever yield would be a measure of the probability that a random couple would possess the distinctive features in question" and "one still could not conclude that the Collinses were probably the guilty couple." According to the court, neither defense counsel nor the jurors could be expected to understand that 1/12,000,000 is not the probability of innocence.

The court's appendix does make it look incomprehensible. The logic behind the formulas is as follows. We generate "cities" of size $n = 12{,}000{,}000$ by flipping a very biased coin 12,000,000 times with the probability of generating a Collins-like couple on each independent toss being $p = 1/n = 1/12{,}000{,}000$. Then we count the number X of Collins-like couples in each of these samples. The expected number of Collins-like couples is $np = 1$, but some cities could have none, some could could have two, three, etc. The court's appendix shows that of all the cities with one or more such couples ($X > 0$), about 41% have two or more Collins-like couples ($X > 1$). In this 41%, the physical traits alone do nothing to incriminate the Collins couple as opposed to any other matching couple.

Put this way, it does seem that a juror would be hard pressed to understand why 1/12,000,000 is not the probability of innocence. But the mathematical exercise in the appendix is unnecessarily complicated. To make the same point — that the probability of innocence given the traits can be much less than the probability of the traits given innocence (1/12,000,000) — consider a population of, say, N = 36 million couples. The single most likely number of couples with the Collins-like traits T is $(1/12{,}000{,}000) \times 36{,}000{,}000 = 3$. Suppose that this is, in fact, the number m of Collins-like couples. The probability that a particular couple in this population, selected on some basis independent of T, is innocent (I) would be $\Pr(I|T) = 2/3$.

The tendency to regard the probability of the traits given innocence as if it were the probability of innocence given the traits is an instance of the "transposition fallacy."[11] The quantity p = 1/12,000,000 is the chance that *if* a couple is innocent, it will have the traits. In symbols,

$$\Pr(T|I) = 1/12{,}000{,}000. \tag{7}$$

Of the m couples with the traits T in a population of n couples, only one is guilty; the remaining m–1 couples are innocent. If each of the m couples is equally likely to be that guilty couple, then probability that if the couple so selected has the traits, it is innocent is

$$\Pr(I|T) = (m-1) / m. \tag{8}$$

The former probability does not equal the later because, in general, $\Pr(A|B)$ does not equal $\Pr(B|A)$. For example, suppose that we draw a card at random from a well shuffled deck. The probability that the card is black given that it is an ace is $\Pr(B|A) = 1/2$. The probability that it is an ace given that it is black is $\Pr(A|B) = 2/26 = 1/13$. These probabilities are hardly equal.

To transpose the probabilities properly, one can use a formula known as Bayes' rule. The formula states how new information (like the characteristics of a Collins-like couple or a match in blood types) alters a probability derived from previously available evidence. Bayes' theorem states that the "posterior odds" (the odds in favor of some hypothesis H given the new evidence) are the "prior odds" in favor of H times a "likelihood ratio" (LR), which states how many times more probable the new evidence E is when H is true than when H is false:

$$\text{Odds}(H|E) = \text{LR} \times \text{Odds}(H). \tag{9}$$

---

[11] In legal circles, this transposition often is designated the "prosecutor's fallacy." Instances of the fallacy, however, can be found in statements of judges and defense counsel as well as prosecutors.

See, e.g., C.G.G. Aitken & Franco Taroni, Statistics and the Evaluation of Evidence for Forensic Scientists (2d ed. 2004); D.H. Kaye et al., The New Wigmore, A Treatise on Evidence: Expert Evidence ch. 12 (2004). For example, if there are exactly $m = 100$ individuals who might have committed a murder and each one is equally likely to be the murderer, then the prior odds on the hypothesis H that the defendant is the murderer are Odds(H) = 1 to 99. (There is one murderer and 99 innocent people in the suspect population.) If evidence E is introduced to show that the murderer left a bloodstain of a type that occurs in a population like that of the suspects only once in every 5000 people, and if defendant's blood is of this type, then it is 5000 times more likely that the murderer would have the incriminating type than an innocent suspect, so LR = 5000. Therefore, the evidence shifts the odds from the prior level of 1 to 99 to the posterior level of 5000 × 1 to 99 = 5000 to 99, which is just over 50 to 1.

From the standpoint of Bayesian decision theory, evidence that produces very large posterior odds amounts to proof "beyond a reasonable doubt." Furthermore, the threshold value depends solely on the "utilities" of the possible outcomes of a correct guilty verdict, a correct acquittal, a false conviction and a false acquittal. Here, the utility of verdict refers to its desirability. For example, if convicting one innocent person is ten times as bad as acquitting a guilty defendant, Bayesian decision theory implies that a guilty verdict requires posterior odds of no less than ten to one.[1]

---

[1]It is simpler to speak in terms of "disutility" or losses. Suppose we let H be the hypothesis that the defendant is guilty, we let the posterior probability of this hypothesis (given all the evidence in the case) be some number p, and we say that it is better to acquit 10 guilty people than to convict one innocent person. Bayesian decision theory recommends the verdict that minimizes the "expected loss." The expected loss for each verdict is the loss that would result, discounted by the probability of these losses coming to pass under each verdict. A guilty verdict has a probability p of being correct but a loss of 0 if it is correct, and a probability $1-p$ of being incorrect but a loss of 10 if it is incorrect. The expected loss for this verdict is therefore

$$0p + 10(1 - p) = 10 - 10p.$$

A not-guilty verdict has a probability $1 - p$ of being correct, and the loss is 0 if it is correct. The same verdict has a probability p of being incorrect, and the loss is 1 in that case. Hence, the expected loss for a not-guilty verdict is

$$1p + 0(1 - p) = p.$$

To minimize the expected loss, the jury should return a verdict of guilty if

$$10 - 10p < p.$$

Solving for p reveals the minimum that $\Pr(G|E)$ must be to justify conviction is 10/11 = .909. In terms of odds, the odds on guilt must exceed 10 to establish guilt beyond a reasonable doubt.

Of course, this result is sensitive to whether p accurately states the probability of guilt and to

4. Collins *redux*. In a case that riveted the nation, former football star O.J. Simpson was charged with murdering his former wife and her friend. DNA analyses were conducted on numerous blood stains found in Simpson's car, home, and other locations. Simpson argued that, under *People v. Collins*, the court should exclude the results. According to his pretrial memorandum of points and authorities:

> In *People v. Collins*, the prosecution sought to compute the probability of a series of characteristics through application of the product rule. This rule holds that the probability of a series of independent events is found by multiplying each of the individual probabilities together. Thus, as the prosecutor suggested in *Collins*, if the individual probabilities of events A, B, C, and D are 1/10 , 1/100 , 1/1000 , and 1/1000 , their combined probability is 1/10 x 1/100 x 1/1000 x 1/1000 = 1/1,000,000,000 (i.e., 1 in 1 billion).
>
> The theory underlying this rule is mathematically sound and uncontroversial. But as the *Collins* Court points out, this is not enough. Meaningful application of the product rule cannot be obtained absent "information as to the degree of interdependence among the ... individual factors." Collins, at 329, fn. 15.
>
> Now assume the frequencies for events A, B, C, and D are the frequencies from the four DNA tests the prosecution seeks to introduce—DQ Alpha, Polymarkers, D1S80, and RFLP. If compelling proof of independence between the frequencies of these four tests is not provided, then we know only that the combined probability of the four tests lies between 1/1,000,000,000 (complete independence) and 1/1,000 (complete dependence). In all likelihood, neither endpoint value is correct and the true combined probability lies somewhere between these two values. But this is an extraordinarily broad range indeed. Whereas a jury might find a 1 in a billion probability compelling proof of identity, it may not find a 1 in 1 thousand probability compelling proof of anything. Indeed, common sense requires the conclusion that people will view these two probability values quite differently.
>
> While the prosecution will attempt to put on proof of independence between the different DNA markers used in each DNA test, the defense knows of no study demonstrating independence between Cellmark's RFLP markers, DQ Alpha, polymarkers, and D1S80. Independence between the frequencies of these tests simply cannot be assumed.
>
> This raises a series of critical questions. First, what is the appropriate joint probability of this series of probabilities that cannot be shown to be independent? Can the scientific community agree on the appropriate estimate? If they cannot, what should be done with the numbers? Does it make sense to provide them to jurors and tell them, in essence, "Here, do what you will with this technical information that members of the scientific and statistical communities do not fully understand or agree upon." What, then, will jurors faced with multiple probabilities do with these numbers once they are presented? How are they to make sense of them? Will they attempt to combine them? If so, what techniques will they use? In all likelihood, a large majority of people will multiply the numbers together. This, of course,

---

the numerical values for the losses. The 10 to 1 ratio is merely illustrative. As to what this critical value might be, see, for example, United States v. Fatico, 458 F. Supp. 388, 410 (E.D.N.Y. 1978); C.M.A. McCauliff, Burdens of Proof: Degrees of Belief, Quanta of Evidence, or Constitutional Guarantees? 35 Vand. L. Rev. 1293, 1325 (1982) (survey of judges). For further discussion of decision theory and the burden of persuasion, see John Kaplan, Decision Theory and the Factfinding Process, 20 Stan. L. Rev. 1065 (1968); D.H. Kaye, The Error of Equal Error Rates, 1 L., Probability, & Risk 3 (2002); D.H. Kaye, Clarifying the Burden of Persuasion: What Bayesian Decision Rules Do and Do Not Do, 3 Int'l J. Evid. & Proof 1 (1999); D.H. Kaye, Apples and Oranges: Confidence Coefficients Versus the Burden of Persuasion, 73 Cornell L. Rev. 54 (1987).

> would presuppose independence without compelling proof of it. Some, perhaps, will add them. This would make no sense at all. Many other, idiosyncratic and equally inappropriate techniques for combining these numbers will surely be used.
>
> Our position is simple. Until the scientific community provides a method for making sense of the multiple coincidental match probabilities, it is extremely prejudicial to throw these numbers at the jury in the hopes they will make sense out of them. . . .
>
> Faced with such a welter of statistics, there is danger the jury will be distracted from considering adequately the serious issues surrounding the reliability of DNA statistical estimates and the problems of PCR contamination. Scientists, lawyers, and judges have considerable trouble engaging and following these debates, how can a jury in this kind of circumstantial case be expected to do so given the current level of controversy?

Memorandum of Points and Authorities in Support of Defendant's Motion to Exclude DNA Evidence, People v. Simpson, No. BA097211 (Super. Ct., Los Angeles County, Oct. 5, 1994). The heading for this argument asserted that "1. *People v. Collins* Requires Compelling Proof of Independence When Offering Multiple Probabilities at a Criminal Trial." Is this a fair reading of *Collins*? What grounds are there for distinguishing *Collins* from *Simpson*?

United States ex rel. DiGiacomo v. Franzen

680 F.2d 515 (7th Cir. 1982) (per curiam)

In this appeal from the denial of a petition for a writ of habeas corpus, petitioner James G. DiGiacomo claims that he was denied a fair trial when the state was allowed to use mathematical probability to identify him as the perpetrator of a crime. We hold that the admission of the challenged testimony violated no right guaranteed by the Constitution and affirm the district court's judgment denying the petition.

I

In March 1977, James G. DiGiacomo was tried in an Illinois state court on charges of rape, deviate sexual assault, aggravated kidnapping, and battery. The principal witness against DiGiacomo was Patricia Marik, the victim of the assault. Marik testified that DiGiacomo abducted her at knife point from a tavern in Naperville, Illinois, on November 5, 1976, and ordered her to drive him to a cornfield in the country where, after a brief struggle, he forced her to have sexual intercourse with him.

In an effort to bolster Marik's identification of DiGiacomo as her assailant at trial, the state called an expert witness to testify concerning a number of hairs that had been recovered from Marik's automobile after the attack. Sally Dillon, the supervising criminologist at the Illinois Bureau of Identification, testified that she had compared the hairs found in Marik's car with a sample of DiGiacomo's hair and found them to be microscopically similar. She was then asked, over defense counsel's objection, whether she could testify as to the statistical probability of the hair found in Marik's car belonging to someone other than DiGiacomo. Dillon responded that based on a recent study she had read, "the chances of another person belonging to that hair would be one in 4,500."

Several hours after beginning their deliberations, the jury, apparently confused by Dillon's testimony, submitted the following question to the court in writing: "Has it been established by sampling of hair specimens that the defendant was positively proven to have been in the automobile?" After consulting with the parties, the trial judge sent a written response to the jury in which he instructed them that it was their duty to determine the facts from the evidence presented at trial and that he could therefore provide no answer to their question. Neither side objected.

The jury later returned guilty verdicts on each of the charges, and DiGiacomo was sentenced to three concurrent terms of eight to twenty-five years for the kidnapping, rape, and deviate sexual assault, and 364 days, also concurrent, for the battery. . . .

. . . DiGiacomo filed a petition for habeas corpus in the United States District Court for the Northern District of Illinois in which he claimed that the admission of Dillon's testimony regarding the statistical likelihood of the hairs found in Marik's car belonging to him constituted a denial of due process. The district court denied the petition, and this appeal followed.

II

[A] federal court is authorized to issue a writ of habeas corpus in behalf of a person in custody under the judgment of a state court "only on the ground that he is in custody in violation of the Constitution or laws or treaties of the United States." Because the admissibility of evidence in state courts is a matter of state law, evidentiary questions are not subject to federal review . . . unless there is a resultant denial of fundamental fairness or the denial of a specific constitutional right.

In this case, DiGiacomo contends the admission of expert testimony as to the mathematical likelihood of hairs found in Marik's car belonging to him resulted in a denial of fundamental fairness in that it misled the jury into believing that the state had conclusively established that he was in the car. In support of his contention, DiGiacomo cites the Eighth Circuit's decision in United States v. Massey, 594 F.2d 676 (8th Cir. 1979).

In *Massey*, the court held that the trial judge's comments construing expert testimony with respect to comparison of hair samples in terms of mathematical probability of error, coupled with the prosecutor's emphasis upon the mathematical probabilities in his closing argument, constituted plain error . . . and required reversal of the defendant's bank robbery conviction even though no objection had been made at trial. The expert in that case had testified that three of five hairs found in a blue ski mask similar to one worn by one of the perpetrators of the robbery were microscopically similar to the defendant's hair. He was then asked by the trial judge how many people in the country might have similar hair that could not be distinguished. The expert responded that in his own experience there had been only a "couple" cases out of over 2,000 in which he had been unable to distinguish hair from two different individuals. He added, however, that according to a recent study, apparently the same study on which Dillon had based her testimony, there was a one in 4,500 chance of another person having the same hair. In an attempt to clarify the response, the trial judge asked the witness if this meant there was only a one in 4,500 or one in 2,000 chance of his identification being wrong. Although the expert's response was somewhat confusing, the prosecutor later emphasized these numbers throughout his closing argument to the jury, concluding with the statement that by itself "the hair sample would be proof beyond a reasonable doubt because it is so convincing."

In reversing the conviction, the Eighth Circuit held that not only had the Government failed to establish a proper foundation for these mathematical conclusions, but in his closing argument the prosecutor had confused the identification of the hair found in the ski cap with the identification of the perpetrator of the crime. Because of this confusion by the prosecutor and the potential for confusion already inherent in such evidence, the court concluded that plain error had been shown.

DiGiacomo contends that his case is even stronger because the record shows more than a mere possibility that the jury was confused. Here, he contends, it is apparent from the written question the jury submitted to the trial court shortly after beginning its deliberations that the jury was in fact confused by the expert testimony. The jury's confusion, which the trial judge's response wholly failed to remedy, he contends, clearly warrants the granting of federal habeas relief.

We agree that the interjection into the criminal trial process of sophisticated theories of mathematical probability raises a number of serious concerns. As one court has aptly stated, "[m]athematics, a veritable sorcerer in our computerized society, while assisting the trier of fact in the search for truth, must not cast a spell over him." People v. Collins, 68 Cal. 2d 319, 320, 66 Cal. Rptr. 497, 438 P. 2d 33 (1968). While perhaps the most serious danger in admitting evidence of statistical probability in a criminal trial is the possibility that it will be used improperly, the possibility of prejudice also exists even when it is used in accordance with generally accepted principles. In a case involving the admissibility of virtually the same testimony with which we are faced here, the Supreme Court of Minnesota noted:

> Testimony expressing opinions or conclusions in terms of statistical probabilities can make the uncertain seem all but proven, and suggest, by quantification, satisfaction of the

> requirement that guilt be established "beyond a reasonable doubt." See Tribe, Trial by Mathematics, 84 Harv. L. Rev. 1329. . . .

State v. Carlson, 267 N.W. 2d 170 (Minn. 1978). [T]he court concluded in *Carlson* that an expert's testimony regarding the mathematical probability of certain incriminating hairs belonging to someone other than the defendant was improperly received. The court went on to hold, however, that under the facts of that case the error was harmless.

Even though we share in the concern of these courts that the admission of evidence as to mathematical probability in a criminal trial may mislead and confuse the jury, we do not find on the facts before us that its admission here constituted a denial of due process. Unlike *Massey*, the prosecutor in this case did not suggest in his closing argument that the mathematical odds testified to by the expert witness made her identification of the hair specimen virtually certain. In fact, the prosecutor conceded during argument that "some people have hair like that." Furthermore, the prosecutor in this case did not confuse the issue of whether the hairs found in the car were DiGiacomo's with the issue of whether he in fact committed the crime, although DiGiacomo concedes that in this case the questions are one and the same.

Although it may be true, as the question submitted to the trial court would seem to indicate, that one or more members of the jury were nevertheless confused about the significance of the hair identification testimony, we cannot say that this confusion was caused by any error of constitutional magnitude. Generally, the admission of expert testimony is very much a matter within the broad discretion of the trial judge. The Constitution does not and, indeed, cannot guarantee that only completely reliable evidence will be placed before the jury. Although it does demand that a defendant be given a full and fair opportunity to challenge whatever evidence is admitted, DiGiacomo was afforded that opportunity here. Through his counsel, he was free to challenge Dillon's testimony if it was not true, or clarify it if it was misleading. He was also free to call his own expert if he thought Dillon's testimony was at odds with the established views of the scientific community. DiGiacomo in fact did none of these things. No attempt was made to cross-examine Dillon regarding her testimony that the hairs found in Marik's car belonged to the defendant.

Even now, DiGiacomo does not claim that Dillon was wrong in her conclusion as to the likelihood of the hair found in Marik's car belonging to someone other than him. His contention is only that she should not have been allowed to express that conclusion in terms of mathematical probability. Instead, he contends she should have stated only whether or not the hairs were similar. But to limit her testimony in this way would have robbed the state of the full probative value of its evidence. To say that the defendant's hair is merely similar to hair found in the victim's automobile is significantly different than saying that there's a one in 4,500 chance of it belonging to someone else. If the expert's testimony is the latter, we know of no constitutional principle by which its admission could be held improper. While the better practice may be for the court specifically to instruct the jury on the limitations of mathematical probability whenever such evidence is admitted, we have no authority to impose such a rule upon the Illinois courts. Thus, we are unable to say that DiGiacomo's conviction resulted from a denial of any right guaranteed by the Constitution.

Of course, jury confusion by itself, even when not the product of a constitutional violation, could justify the granting of habeas relief if it resulted in a verdict that no rational trier of fact could have reached on the basis of the evidence presented. But DiGiacomo does not argue that no rational trier of fact could have found him guilty and, even if he did, the record does not support such a claim. Marik's positive identification of him as the man who had assaulted her together with the other evidence introduced by the state was more than sufficient to support a rational jury's verdict of guilty.

The district court's judgment denying the petition is affirmed.

NOTES

1. *Objections to the 1/4500 figure*. Does the court of appeals hold that the probability of 1/4500 was properly admitted? What objections could one raise to its admission? Did the analyst succumb to the transposition fallacy in presenting the figure?

2. *Source of the figure*. The studies that generated probabilities like the 1/4500 figure are B.D. Gaudette & E.S. Keeping, An Attempt at Determining Probabilities in Human Scalp Hair Comparison, 19 J. Forensic Sci. 599 (1974), and B.D. Gaudette & E.S. Keeping, Probabilities and Human Pubic Hair Comparison, 21 J. Forensic Sci. 514 (1976). As explained in the first of these articles,

> If nine dissimilar hairs [enough to capture the variety of hair present on a scalp] are independently chosen to represent the hairs on the scalp of Individual B, the chance that the single hair from A is distinguishable from all nine of B's may be taken as . . . approximately 1 – (1/4500). This means that the probability that in at least one of the nine cases the two hairs examined would be indistinguishable is about 1/4500.

This estimate is easily challenged. See Panel on Statistical Assessments as Evidence in the Courts, The Evolving Role of Statistical Assessments as Evidence in the Courts 64-67 (Stephen E. Fienberg ed., 1989). Thus, probability assessments for microscopic hair identification remain controversial. Compare Clive A. Stafford & Patrick D. Goodman, Forensic Hair Analysis: Nineteenth Century Science or Twentieth Century Snake Oil?, 27 Colum. Hum. Rts. L. Rev. 227 (1996), and Larry Miller, Procedural Bias in Forensic Science Examinations of Human Hair, 11 Law & Hum. Behav. 157 (1987), with Edward Imwinkelried, Forensic Hair

Analysis: The Case Against the Underemployment of Scientific Evidence, 39 Wash. & Lee L. Rev. 41 (1982).

State v. Kim

398 N.W. 2d 544 (Minn. 1987)

WAHL, JUSTICE.

This appeal questions the standard that governs state appeals of pretrial orders in criminal prosecutions as well as the propriety of the trial court ruling in this case. Joon Kyu Kim is charged with accomplishing sexual penetration by use of force or coercion . . . . At a pretrial hearing, the state proferred scientific evidence in the form of blood test results linking Kim to semen found at the scene of the alleged rape and a statistical analysis of the frequency with which Kim's blood type occurred in the local male population. The trial court ruled that the blood test results and expert testimony that the test results were consistent with Kim having been the source of the semen could be admitted at trial, but ruled that the statistical population frequency evidence was to be excluded. . . .

The facts in this case, as derived from police reports, indicate the complainant reported to police that on December 10, 1984, Joon Kyu Kim, her employer, had forcible, nonconsensual sexual intercourse with her. The complainant and her husband were employed as managers of a St. Paul apartment complex owned by Kim. On the evening of December 10, 1984, the complainant told police she was home alone. She and her husband had quarreled earlier in the evening and he had left the apartment. Her husband told police that after he left the apartment, he went to talk with Kim and they discussed, among other things, his marital problems. About 10 p.m., the complainant reported, Kim showed up at her apartment and began to talk about her marital relationship, telling her she wasn't having enough sex with her husband and that he would show her how. She said Kim then grabbed her breast, but she pulled away and told him to leave. Kim grabbed her again, she told police, forced her into the bedroom and onto the bed. She said she felt very afraid. He removed his clothing and her clothing and then climbed on top of her, she stated, sucking on her breasts and penetrating her vagina with his penis until he ejaculated. She said that as he left, Kim gave her a twenty dollar bill and told her next time it would be thirty dollars. He also told her she wouldn't call the police because she "needed the job too much." The complainant contacted the police shortly after Kim left the apartment.

At the time the complainant reported the incident, she turned over to police the sheet from the bed where she alleged she had been raped, a pair of panties she was wearing, a sanitary pad, a towel she had used to clean herself, and the twenty dollar bill she alleged Kim had given her. At the hospital, swab samples were taken of fluid present in the complainant's vagina. The Bureau of Criminal Apprehension Laboratory (BCA) found semen present on the bed sheet and on the vaginal swabs.

Kim was questioned by police the next day and denied having had sexual intercourse, consensual or nonconsensual, with the complainant. He admitted he had gone to her apartment that night, but stated he went there to fire her from her job as caretaker. He claimed her accusation was motivated by this firing. He pleaded not guilty to the criminal sexual conduct charges subsequently filed against him.

The trial court, on the state's motion, ordered samples of Kim's blood, saliva and hair taken for purposes of comparing his blood type with the semen found on the bed sheet and in the complainant's body.[1] Comparison samples of blood were also taken from the complainant and from her husband. The samples were tested at the BCA Lab using blood type testing (ABO system) and electrophoresis testing, a procedure that identifies distinctive enzymatic genetic markers present in the blood and bodily fluids. The tests were repeated at the Minneapolis War Memorial Blood Bank and the BCA results were replicated. The BCA Lab analyst was prepared to offer testimony that the semen found in the complainant's body and on the bed sheet was consistent with Kim's blood type and PGM reading.[2] Further, the analyst was prepared to testify that 96.4 percent of males in the Twin Cities metropolitan population, but not Kim, could be excluded on the basis of this combination of blood factors as possible sources of the semen found on the bed sheet.

Kim objected to all of the scientific evidence at the pretrial hearing. As to the statistical population frequency evidence, he argued that its prejudicial impact outweighed its probative value. The trial court excluded the statistical population frequency evidence under the rule of State v. Boyd, 331 N.W. 2d 480 (Minn. 1983). This pretrial appeal followed. . . .

[W]e consider first whether the state met its burden of clearly establishing that the trial court's suppression order was erroneous. The court of appeals held that the state did not meet this burden and concluded that the trial court had properly interpreted and applied the rule of our decision in *Boyd* to suppress the statistical population frequency evidence. The defendant in *Boyd* was prosecuted for criminal sexual conduct in the third degree for having sexual intercourse with a 14-year-old girl, who became pregnant and gave birth as a result. We held that expert testimony that there was a 99.911 percent likelihood of paternity, based on population frequency statistics applied to interpret blood test results, must be excluded. "[T]here is a real danger," we stated, "that the jury will use the [statistical population frequency] evidence as a measure of the probability of the defendant's

---

[1]The majority of people, including Kim, secrete their blood type in their body fluids, including semen, saliva, etc.

[2]PGM is an enzyme. It is a genetic marker that may be detected in the blood by use of the electrophoresis testing process.

guilt or innocence, and that the evidence will thereby undermine the presumption of innocence, erode the values served by the reasonable doubt standard, and dehumanize our system of justice."

The state argues in this appeal that the statistical evidence it seeks to introduce against Kim can be distinguished from that [sic] we disapproved in *Boyd*. The difference between the evidence in *Boyd* — that 99.911 percent of the population, but not the defendant, could be excluded as donors — and the evidence it has proferred in this case — that 3.6 percent of the population, including the defendant, are possible donors — is the difference between inclusion and exclusion. The state contends that when statistics are stated as an exclusion figure, as in *Boyd*, the risk is greater that the jury will interpret the statistical percentage as a statement of the probability of the defendant's guilt. By contrast, when stated as an inclusion figure, the danger of such quantification is urged to be less.

The court of appeals correctly rejected this purported distinction, stating that *Boyd* "do[es] not focus on the nature of the statistics but rather on the impact of the statistics on the trier of fact." The danger we recognized in *Boyd* is that statistics on the frequency with which certain blood type combinations occur in a population will be understood by the jury to be a quantification of the likelihood that the defendant, who shares that unique combination of blood characteristics, is guilty. This danger exists as much in an inclusion as in an exclusion figure because, as the trial court noted, faced with an exclusion percentage, a jury will naturally convert it into an inclusion percentage. Because we cannot meaningfully distinguish the evidence offered in *Boyd* from that in the case now before us, we conclude that *Boyd* controls. We affirm the decision of the court of appeals and hold that the state has not clearly and unequivocally shown that the trial court order suppressing statistical population frequency evidence was erroneous.

The state next argues that if its proferred evidence cannot be distinguished from the evidence we disapproved in *Boyd*, we should modify or overrule *Boyd* but has presented no new or compelling argument. The state argues that the effect of *Boyd* is to exclude from the factfinding process reliable scientific evidence with great probative evidentiary value. The probative value of such evidence is, however, not of controlling significance in the analysis we adopted in *Boyd*. Under the Minnesota Rules of Evidence, relevant evidence may be excluded if its probative value is substantially outweighed by the danger of unfair prejudice. In *Boyd*, we clearly determined that the danger of population frequency statistics used to analyze blood test results unfairly prejudicing a defendant due to its "potentially exaggerated impact on the trier of fact" outweighed any probative value.

Boyd does not foreclose the use of expert interpretations of blood test results.[6] . . . As in *Boyd*, the expert called by the state in this case should not be permitted to express an opinion as to the probability that the semen is Kim's and should not be permitted to get around this by expressing the opinion in terms of the percentage of men in the general population with the same frequency of combinations of blood types. The expert should be permitted to testify, however, as to the basic theory underlying blood testing, to testify that not one of the individual tests excluded Kim as a source of the semen and to give the percentage of people in the general population with each of the individual blood types, and to express an opinion that scientific evidence is consistent with Kim having been the source of the semen. . . .

Affirmed.

KELLEY, JUSTICE (dissenting):

With utmost reluctance, I respectfully dissent. . . . *Carlson* is less than nine years old and *Boyd* is slightly over three. Both decisions were decided by a unanimous court. Normally, desired stability in the law is seldom enhanced by calling into question the correctness of precedents. Especially is that true when the questioned precedents are of such recent vintage. My reluctance to pen this dissent is prompted not only by that laudatory and necessary stare decisis consideration, but additionally because I joined with the remainder of the court in *State v. Boyd*. However, no violence is done to that laudatory and venerable doctrine of stare decisis when we re-examine a ruling that appears to be clearly wrong; nor is any valid public purpose promoted by embedding in our body of law an incorrect or outmoded decision. Further study and consideration of the issues in those two cases convinces me that both were wrongly decided.

This court in both *State v. Carlson* and *State v. Boyd*, and the majority in the instant case, relied upon an article written by Professor Tribe. In my opinion, the conclusions reached by Professor Tribe . . . in 1971 have since been successfully challenged by other researchers. Moreover, the assumptions upon which Tribe based his conclusions, in my opinion, have been fairly rebutted by other writers.

In a criminal case, we are concerned that no conviction shall be upheld unless guilt has been established beyond a reasonable doubt. In any system of criminal justice, a convicted person will necessarily be convicted on something less than absolute proof. Indeed, because in almost every case some doubt does exist, the law uses the expression "beyond a reasonable doubt" instead of "beyond any doubt." Thus, jurors routinely use probabilities in assessing whether the state has met its evidentiary burden. . . . The question is whether it is preferable to submit to the jury properly established scientific and mathematical probabilities of the existence of

---

[6]The concern about the prejudicial effect of blood test evidence expressed in *Boyd* does not apply outside of the context of criminal prosecutions. Blood test results and expert explanations thereof are admissible in evidence, for example, in a paternity proceeding.

a fact to bear on its decision-making process than to ignore reality by asserting people are convicted only when absolute proof is available when, in fact, absolute proof is rarely, if ever, at hand. Therefore, I conclude . . . that "exclusion of mathematical guides to aid a fact finder, while avoiding some problems, exposes the fact-finding process to the heuristic biases of intuitive decision making."

I suggest that . . . the time may now have come for us to reconsider [*Carlson* and *Boyd*]. Just a few years short of the 21st century, perhaps courts should utilize those kinds of empirical, mathematical, scientific and statistical analyses used by all sorts of professional people including those in science, industry, engineering, administration, education and planning. . . . I agree with the Utah court when it said in rejecting our holding in *State v. Carlson*, "[We do] not share that philosophy, having a higher opinion of the jury's ability to weigh the credibility of such figures when properly presented and challenged." State v. Clayton, 646 P.2d 723, 727 n.1 (Utah 1982); see also E. Cleary, McCormick on Evidence § 210, at 655 (3d ed. 1984).

In my view the specific facts of this case demonstrate the shortcomings of excluding empirical scientific evidence. The proffered evidence involves the use of population frequency statistics in conjunction with individualization typing-test results. Based upon *Boyd*, the majority sustains the court's ruling permitting introduction of the test results but excluding the population frequency statistics. . . . Courts of other jurisdictions addressing the issue are increasingly recognizing the necessity of providing the fact finder with both the test results and the population frequency statistics. See, e.g., Davis v. State, 476 N.E.2d 127, 135-36 (Ind. Ct. App.1985) (noting that the approach taken by *Carlson* and *Boyd* "has been rejected by an impressive myriad of courts and commentators."); State v. Washington, 229 Kan. 47, 59, 622 P.2d 986, 995 (1981).

I agree. In my view, not to permit this evidence evinces on our part a distrust of both the abilities of the bar to demonstrate any weaknesses in analysis as well as our distrust of the ability of the jury to consider empirical scientific and mathematical statistical evidence with the same discrimination that it has to use, for example, in considering the opinion of a psychiatrist that the accused is insane.

Accordingly, even though with reluctance, I would reverse the trial court and overrule *State v. Carlson* and *State v. Boyd*.

NOTES

1. *The Minnesota rule and the virtues and vices of quantification*. What probability figures, if any, are admissible in Minnesota? Should forensic scientists be encouraged to make quantitative statements of crucial probabilities? To Dr. Walls the answer is clear: "it would obviously be quite wrong not to be precise instead of vague if the known facts make that possible." Do you agree? *Kim* reveals that some courts and commentators have serious reservations about "probability evidence." Even so, as the dissent in *Kim* indicates, Minnesota is the only state or federal jurisdiction categorically to exclude apparently well-founded, numerically expressed probabilities and population proportions. And, even in Minnesota, the legislature adopted a bill to overturn the exclusionary rule, and the state supreme court created a "DNA exception" to the rule. State v. Bloom, 516 N.W. 2d 159 (Minn. 1994).

The evidentiary problems associated with testimony as to such numbers are discussed in D.H. Kaye et al., The New Wigmore, A Treatise on Evidence: Expert Evidence ch. 12 (2004). The introduction of probabilities in the courtroom also has attracted the attention of psychologists. A first wave of empirical studies of the impact on mock jurors of statistics and probabilities, framed and explained in different ways, is reviewed in D.H. Kaye & J. Koehler, Can Jurors Understand Probabilistic Evidence? 154 J. Royal Stat. Soc'y (A) 75 (1991), and William C. Thompson, Are Juries Competent to Evaluate Statistical Evidence? 52 Law & Contemp. Probs. 9 (1989). More recent research includes Valerie Hans et al., Science in the Jury Box: Do Jurors Understand MtDNA Evidence? (in preparation); J.J. Koehler, When Are People Persuaded By DNA Match Statistics?, 25 L. & Hum. Behav. 493 (2001); J.J. Koehler & L. Macchi, Thinking About Low Probability Events: An Exemplar Cuing Theory, 15 Psych. Sci. 540 (2004); Dale A. Nance & Scott B. Morris, Juror Understanding of DNA Evidence: An Empirical Assessment of Presentation Formats for Trace Evidence with a Relatively Small Random-match Probability, 34 J. Legal Stud. 395 (2005); Dale A. Nance & Scott B. Morris, An Empirical Assessment of Presentation Formats for Trace Evidence with a Relatively Large and Quantifiable Random Match Probability, 42 Jurimetrics J. 403 (2002); Jason Schklar & Shari Diamond, Juror Reactions to DNA Evidence: Errors and Expectancies, 23 Law & Hum. Behav. 159 (1999); Brian C. Smith, Steven D. Penrod, Amy L. Otto, & Roger C. Park, Jurors' Use of Probabilistic Evidence, 20 Law & Hum. Behav. 49 (1996).

One finding of these and other studies of probability judgments, is that subjects seem to give numerical probabilities less weight than would be prescribed by Bayes' rule. However, there could be "framing effects." One researcher conducted experiments in which students were presented with the following four different but "legitimate, mathematically comparable ways to describe a one in one thousand DNA match statistic":

> 1. The probability that the suspect would match the blood specimen if he were not the source is 0.1%.
> 2. The frequency with which the suspect would match the blood specimen if he were not the source is one in one thousand.
> 3. One tenth of one percent of the people in Houston who are not the source would also match the blood drops.

4. One in one thousand people in Houston who are not the source would also match the blood drops.

Jonathan J. Koehler, The Psychology of Numbers in the Courtroom: How to Make DNA-match Statistics Seem Impressive or Insufficient, 74 S. Cal. L. Rev. 1277-78 (2001). What differences in the impact on the students, if any, do you think might be associated with these different ways of framing the "one in one thousand" statistic? Should the courts apply the evidentiary policy embodied in Federal Rule of Evidence 403 (balancing probative value against unfair prejudice) to prescribe (or to forbid) a particular format? See Kaye et al., supra.

2. *Vices of qualitative testimony*. Qualitative expressions such as "likely" or "rare" are subject to a broad range of interpretation, even within a single professional group. See Augustine Kong et al., How Medical Professionals Evaluate Expressions of Probability, 315 New Eng. J. Med. 740 (1986); Detlof von Winterfeldt & Ward Edwards, Decision Analysis and Behavioral Research 98-99 (1986); cf. Steven Morse, Crazy Behavior, Morals and Science: An Analysis of Mental Health Law, 51 S. Cal. L. Rev. 527, 591 (1978). Should experts be prohibited from using such terms when quantitative alternatives are available? What if the state of the science does not justify quantitative estimates? Should expert testimony of a "match" be excluded, either because good science demands quantitative analyses or because, without numbers, the jury cannot gauge the probative value of a match? This question has received considerable attention in cases involving fingerprints, handwriting, toolmarks, and bullet lead comparisons.[7] See D.H. Kaye, The Current State of Bullet Lead Evidence, __ Jurimetrics J. __ (2006).

---

[7]It surfaced in two very prominent cases. In the wrongful death cases brought against O.J. Simpson following his acquittal for the murders of Nicole Brown Simpson and Ronald Goldman, Simpson moved to exclude testimony of a "match" between certain hairs and fibers. See Plaintiffs' Reply Memorandum in Opposition to Defendant Orenthal James Simpson's Motion in Limine to Preclude the Use of the Term "Match" in the Context of Hair and Fiber Evidence, Rufo v. Simpson, 1996 WL 514130 (Cal. Super. Ct., Los Angeles County, Nos. SC031947, SC036340 & SC036876, Sept. 6, 1996). Likewise, in the trials of Timothy McVeigh and James Nichols following the bombing of the federal building in Oklahoma City, the court, the defendants sought to limit and undermine the testimony of FBI toolmark analysts who could not validate their belief that marks from a drill bit used to open a padlock established that whose drill bit was used. See Testimony of James Cadigan in *United States v. McVeigh*, No. 96-CR-68 (D. Colo. May 5, 1997), and Testimony of James Cadigan and George Krivosta in *United States v. Nichols*, No. 96-CR-68 (D. Colo. Nov. 10, 1997).