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When evidence with a scientific basis is offered, two fundamental questions arise. First, should it be admitted? Second, if so, how should it be assessed? There are numerous participants who might play a role in deciding these questions—the jury (on the second question only), the parties (through counsel), expert witnesses on each side, the trial court, the forces controlling the judicial system (which include, but are not limited to, the appellate courts), and the scientific establishment. In this Article, I will suggest that together, the last two—the forces controlling the judicial system and the scientific establishment—have a large role to play in determining how statistically based evidence shall be explained to, and may be used by, the jury. For this purpose, the scientific establishment includes not only statistical experts but also legal academics with an expertise in problems of inference and proof; they should assist the judicial system in devising pattern instructions to help the jury avoid well-recognized pitfalls in handling statistical evidence in certain well-defined and recurrent circumstances. Trial courts should be required to give those instructions in the prescribed circumstances, and neither the parties (themselves or their counsel) nor their experts should be allowed to say anything at variance with those instructions.

Our system with respect to scientifically based evidence is controlled to a large extent by the parties and their experts. The parties decide what experts to call, and the experts testify to the conclusions that can be drawn from the evidence. There are limitations, of course. The court must determine that the expert is sufficiently qualified to testify to an opinion on the given subject matter, and that the subject matter itself is sufficiently reputable, under *Daubert* or *Frye* or whatever standard is applicable in the jurisdiction. But these constraints give the parties a great deal of free rein, and once the evidence is admitted, the lawyers ordinarily have wide leeway in making arguments based on the evidence. That is usually all for the good, and indeed I believe that trial judges should ordinarily play less of a role than they do in filtering scientific evidence for the jury. In some cases, judges

[*] Professor, University of Michigan Law School. This Article is based on a presentation given at the 2017 Seton Hall Law Review Symposium honoring Michael Risinger, who has long been one of our most insightful, careful, erudite, and influential scholars of evidence law, especially scientific evidence. It was an honor and a privilege to participate in the symposium.

should decide as a matter of law that a body of evidence is not sufficient for the case to reach the jury, but judges ought rarely, if ever, decide that a given piece of evidence should not be presented to the jury because the jurors are too likely to overvalue it.[1]

But I think courts should have a far different attitude when there is a plain danger that jurors may treat evidence in an illogical manner. This danger arises with great frequency when parties present evidence that two items have a common source. The evidence tends to center on two probabilities—a high probability, often close to one, that if the items did in fact have a common source, they would bear some similarity that they in fact do; and a low probability, sometimes infinitesimally low, that if the items did *not* share a common source, they would not bear that similarity. And the problem is often exacerbated, rather than ameliorated, by the statements of expert witnesses and of counsel at trial. I will focus on the two fallacies identified and labeled by Bill Thompson and Edward Schumann three decades ago: the prosecutor's fallacy and the defense attorney's fallacy.[2]

Suppose, to take an example now offered by Thompson, a blood stain from a crime scene and a reference blood sample taken from the accused have the same DNA profile and that matching profiles are estimated to occur in 1 person among 10 million people in the Caucasian-American population. And suppose further that it is certain that the crime was committed by a Caucasian-American. Then the prosecutor's fallacy consists of inferring from this evidence that the odds that the crime-scene stain came from someone other than the accused are only 1 in 10 million.

That is just plain wrong. The 1-in-10-million random match probability is just one of the ingredients we must know to assess the probability that the accused is the source of the crime-scene stain. Another is the probability that the match would appear if in fact the accused was the source. If we can safely assume in a case like this that this probability is very close to 1, then it does not pose a substantial problem. So those are two components necessary to assess the probability, in light of the DNA match, that the accused is the source of the crime-scene stain. But there is another crucial element that the DNA evidence does not help assess—the prior odds, that is, the odds based on all the evidence *other than* the DNA evidence that the accused was the source of the crime-scene stain. If those odds are assessed as exactly even—1 to 1—then the posterior odds (that is, the odds taking into account the DNA evidence) that the accused was the source of the crime-

[1] Richard D. Friedman, *Squeezing* Daubert *Out of the Picture*, 33 SETON HALL L. REV. 1047 (2003).

[2] William C. Thompson & Edward L. Schumann, *Interpretation of Statistical Evidence in Criminal Trials: The Prosecutor's Fallacy and the Defense Attorney's Fallacy*, 11 LAW & HUM. BEHAV. 167 (1987).

scene stain would in fact be 10 million to 1. But if the prior odds are significantly different, so too are the posterior odds. Most significantly, if the prior odds are very small, as they should be deemed to be if there is not substantial other evidence linking the accused to the crime-scene stain, then the posterior odds may be small as well; if, for example, the prior odds are 1 to 7.5 billion (the accused is just as likely as every other person on earth to be the source of the stain), the posterior odds would be just 1 to 750.

The DNA evidence cannot help assess the prior odds. The expert witness has no valid basis for making an assessment, and it would be improper for the expert to offer such an assessment, or for that matter, to offer an assessment of the overall odds that the accused is the source of the crime-scene stain. That is the jury's job.

Now consider the defense attorney's fallacy. Suppose the defendant has a characteristic that the perpetrator of the crime is known to have, and that only a small, but not infinitesimal, percentage of the population shares that characteristic. "So it appears that whoever committed this crime was one-handed," defense counsel might argue. "And my client is one-handed. But this means nothing. So are thousands of other people in this country alone." It is true that if there were no other evidence in the case, one could not ascribe guilt to the accused based simply on his one-handedness; indeed, the odds of guilt would remain very low. But no sensible prosecutor would bring a case if that were the *only* evidence against the accused. Presumably there is some other evidence making it at least plausible, in the jury's eyes, that the accused committed the crime, even without taking the one-handedness into account, and the evidence of one-handedness should increase the jury's assessment of the odds of guilt many times, perhaps on the order of 8,000 times or more.[3]

And so we have a complexity. First, the expert can inform the jury about the probability that the evidence would arise if the accused is, or is not, the source of the crime-scene stain, but those in themselves do not tell the jury what it really needs to assess, the probability given the evidence that the accused was the source of that stain—and of course, they in themselves do not tell the jury what it ultimately needs to assess—the probability that the accused in fact committed the crime. Second, assessing those critical probabilities depends in very large part on all the other evidence in the case; it is the jury's job to evaluate that evidence, and the expert can offer no help

[3] There are approximately 41,000 people in the United States missing a hand or an arm. *Statistics on Hand and Arm Loss*, INDUS. SAFETY & HYGIENE NEWS (Feb. 4, 2014), http://www.ishn.com/articles/97844-statistics-on-hand-and-arm-loss. The population of the United States is over 327 million. U.S. Census Bureau, *U.S. and World Population Clock*, https://www.census.gov/popclock/ (last visited Mar. 4, 2018). So approximately 1 in 8,000 people in the United States is missing a hand or an arm.

in doing so. And third, the jury must make the connection between all the other evidence in the case and the data indicating the significance of the particular identification evidence—that is, the jury must determine how to reassess the probability of guilt in light of that data. This reassessment is difficult for many people; jurors may do it badly,[4] and lawyers and even expert witnesses—who likely do not have expertise in probabilistic analysis—may well mislead them rather than provide genuine assistance.[5]

So what should we do? Thompson flirts, as others have done,[6] with the idea of using non-numeric verbal descriptions of the strength of the identification evidence. I am skeptical of the value of such evidence for several reasons. First, verbal descriptions by definition give up on the precision that numerical information conveys.[7] If one says the evidence provides "strong" support for the proposition of identity, what is the jury to make of that—how strong is "strong"? Second, and relatedly, verbal descriptions fail to convey the power that very large (or very small) numbers do. If the evidence is that the accused and the perpetrator share a trait, and the probability that a randomly chosen person would share that trait is only 1 in 100 trillion, I do not think that saying that the evidence provides "extremely strong" support for identity suffices. Third, verbal scales are by nature non-continuous. Where should the boundary be drawn between "strong" and "very strong"? And if the different wording is meant to convey a substantial difference in effect, is it not unsettling that a very small difference in the numbers is sufficient to move the description from one category to another? Finally, a verbal scale does not necessarily solve the problem that the jury may misuse the evidence, and especially that it might commit the prosecutor's fallacy. That is, if the jury is told that the evidence provides "extremely strong" support for identity, we have no guarantee that the jury will use that evidence to reassess in a proper manner the probability

[4] Thompson provides some evidence that they tend to do it reasonably well with respect to some types of evidence. William C. Thompson, *How Should Forensic Scientists Present Source Conclusions?*, 48 SETON HALL L. REV. 773 (2018).

[5] *E.g.*, David H. Kaye & Jonathan J. Koehler, *Can Jurors Understand Probabilistic Evidence?*, 154 J. ROYAL STAT. SOC'Y, SERIES A, 75 (1991), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1487747 (reviewing empirical studies and concluding that they indicate a tendency on the part of jurors to give too little value to statistical evidence when they are also presented with other evidence).

[6] Thompson, *supra* note 4; EUROPEAN NETWORK OF FORENSIC SCI. INSTS., ENFSI GUIDELINE FOR EVALUATIVE REPORTING IN FORENSIC SCIENCE: STRENGTHENING THE EVALUATION OF FORENSIC RESULTS ACROSS EUROPE (STEOFRAE) 16–17 (2015), http://enfsi.eu/wp-content/uploads/2016/09/m1_guideline.pdf; Ian W. Evett, *Bayesian Inference and Forensic Science: Problems and Perspectives*, 36 J. ROYAL STAT. SOC'Y, SERIES D 99, 103 (1987) (presenting, without endorsing, a table of such descriptions).

[7] Of course, the numbers, while precise, may not be accurate, and if the expert is ascribing numbers without a good basis, it may be that the numbers should not be presented to the jury. But this is a separate problem.

of identity; it may be that the jury will simply infer the conclusion that the probability of identity is extremely high.

I think we need another approach. Although ordinarily the presentation of evidence and the argumentation from it are in the hands of the parties and their witnesses, there are limits. And I think we should recognize and implement this limitation: a party or a witness should not be allowed to suggest that the jury operate in a demonstrably illogical manner.

The validity of this limitation may not be self-evident. Consider by analogy the law with respect to judicial notice of adjudicative facts. I will use as an exemplar of that law Federal Rule of Evidence 201. That Rule sets a high standard for such notice—the factual proposition in question must not be "subject to reasonable dispute," and either it "is generally known within the trial court's territorial jurisdiction" or it "can be accurately and readily determined from sources whose accuracy cannot reasonably be questioned."[8] Now, if that rigorous standard is met in a civil case, the Rule prescribes that "the court must instruct the jury to accept the noticed fact as conclusive."[9] But in a criminal case, even given that the proposition is not subject to reasonable dispute, "the court must instruct the jury that it may or may not accept the noticed fact as conclusive."[10] So if a party in a criminal case can suggest that the jury act on the basis of a factual proposition that the court believes is demonstrably false, can a party suggest that the jury act in a demonstrably illogical manner?

I do not believe so. For one thing, I believe that the "may or may not accept" language of Rule 201 is overly cautious, a product of an arguably overly aggressive implementation of the sound proposition that only the jury can determine guilt of a criminal defendant,[11] conjoined with a misplaced emphasis on symmetry.[12] It may make sense that the jury should not be instructed that it must treat a given fact as established unfavorably to an accused; it does not follow that a jury should not be instructed that it must treat a fact as established favorably to an accused.

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[8] FED. R. EVID. 201(b).

[9] FED. R. EVID. 201(f).

[10] *Id.*

[11] That the implementation may be overly aggressive is supported by D. Michael Risinger, *John Henry Wigmore, Johnny Lynn Old Chief, and "Legitimate Moral Force"—Keeping the Courtroom Safe for Heartstrings and Gore*, 49 HASTINGS L.J. 403, 407 n.14 (1998) (arguing that a binding instruction is preferable in the context of judicial notice and other "non-evidence driven mechanisms," and "presents no real constitutional issue as long as the jury is clearly free to return a general verdict of not guilty").

[12] *See, e.g.*, Robert Laurence, *The Bothersome Need for Asymmetry in Any Federally Dictated Rule of Recognition for the Enforcement of Money Judgments Across Indian Reservation Boundaries*, 27 CONN. L. REV. 979, 985 (1995) (offering an asymmetrical proposal, defending an "unrepentant" attitude about the asymmetry, and noting that "[t]he universe itself is asymmetrical").

But in any event, the strictures that apply to judicial notice should not apply in this context. The present question is not whether a given fact bearing on the litigation is true; it is rather a matter of fundamental logic. A party or a witness should not be allowed to encourage the jury to violate basic principles of logic—and that is all the more true when the error would be in favor of the prosecutor.

The better analogy is not to the treatment of adjudicative facts but to that of legislative facts—facts on which the determination of the law depends. By its explicit terms, Rule 201 does not cover judicial notice of such facts.[13] This is appropriate because the situation governing judicial notice of legislative facts is altogether different from that governing judicial notice of adjudicative facts. When the content of the law depends on a legislative fact, ultimately that fact must be determined (so far as the judicial system is concerned) by the court of last resort in the jurisdiction; otherwise the law might differ from court to court or even from case to case.[14] That court is therefore not constrained by the record or arguments made by the parties or by the findings made by the trial court. To take notice of a legislative fact, a court need not attain the level of certainty necessary for judicial notice of an adjudicative fact; given that the court needs to determine the law, it may have to determine (or at least act as if it has determined) a legislative fact one way or the other in the face of substantial uncertainty. And even given that uncertainty, the court operates as if the fact that it notices is absolutely true: it does not instruct the jury as to the fact, because there is no need to, but rather determines the law on the basis of the fact, and proceeds from there.

With respect to principles of logic, there is not the same peremptory demand as to system-wide consistency as exists with respect to legislative facts. But such principles transcend a single case—they frequently become critical in litigation—and there is no good reason *not* to apply them correctly and consistently. Perhaps even more clearly, there is no good reason to allow the jury to be *misinformed* about them. Experience has shown that expert witnesses and lawyers cannot be relied on to provide good advice to jurors in this respect, or even to avoid misinforming them; nor is there any reason to have confidence in trial judges—or for that matter, individual appellate judges—in this respect. This is a matter that should be implemented system-wide, with the participation of the scientific establishment, and for this purpose, I count legal academics with expertise in matters of inference and proof as part of the scientific establishment.

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[13] FED. R. EVID. 201(a).

[14] The parenthetical qualification is in recognition that the law might be altered from outside the judicial system, such as by legislative or constitutional amendment.

In other words, what are needed are pattern jury instructions for frequently recurring situations, expressing logical principles for assessing evidence that includes numerified frequency rates or probability assessments. I am not suggesting that courts introduce numbers where they are not already present. Rather, I am saying that in recurrent situations in which the evidence presented by the parties includes numerified frequency rates or probability assessments, the trial court should be directed to give a prescribed instruction that attempts to inform the jury how to combine that evidence with the other evidence in the case, or at least attempts to inform the jurors how to avoid making easily recognizable mistakes. I am suggesting more than perfunctory instructions, but rather attempts at teaching the jury. I doubt that attempts to teach the jury how to operate Bayes' Theorem formally are likely to succeed.[15] I think the most we can hope for is probably to give jurors examples of how to deal with the numbers and to warn them of mistakes that they should avoid.[16]

This is not a simple undertaking. Careful thought must go into what kinds of jury instructions should be given in prescribed categories of situations. As a teaser, I will present below a draft of what such an instruction might look like, for a situation like one of Thompson's hypotheticals, in which the evidence suggests that the accused has a rare trait that the perpetrator did, but one common enough that there are probably numerous other people in the world who share it.

> Members of the jury, the prosecution has presented evidence concerning the DNA profile of the blood in the stain found at the crime scene. According to the prosecution's expert, this profile indicates that the blood could not be the victim's. Furthermore, according to the prosecution's expert, she has compared the profile of the DNA found in that blood to the DNA profile of the accused, which according to prosecution evidence is known from a sample taken directly from the accused. And the expert has testified that the profile taken from the crime-scene stain is just what one would expect if the accused was the source of the stain. Furthermore, according to the prosecution's expert, if a randomly chosen member of the Caucasian population of the United States

[15] *Cf.* Michael O. Finkelstein & William B. Fairley, *The Continuing Debate Over Mathematics in the Law of Evidence: A Comment on "Trial by Mathematics,"* 84 HARV. L. REV. 1801 (1971); Michael Finkelstein & William Fairley, *A Bayesian Approach to Identification Evidence*, 83 HARV. L. REV. 489 (1970).

[16] My focus here is on the situation in which the expert offers numerified evidence. But if the expert does not do so, I believe the same approach would be useful. If, for example, the expert testified that the evidence provides "extremely strong support" for the proposition of common source, the court should explain both that this does not mean that the proposition is extremely probable and why it does not mean that.

were the source of the stain, there would only be one chance in 10 million that this profile would appear in the DNA.

Now, you have to determine whether you believe all this evidence. Were the samples taken as the prosecution evidence indicates? Were the tests performed separately and properly on the crime-scene stain and on the sample taken from the accused? (If by mistake or otherwise, one sample was tested twice, evidence that the same profile appeared both times would be meaningless.) Were the profiles as described? Do the two profiles have the similarities that the prosecution's expert contends? Is the profile found on the crime-scene stain as rare as the prosecution contends?

But even if you accept all the prosecution evidence concerning DNA, you then must consider what significance to attach to it. You must put the DNA evidence together with all the other evidence in the case to determine whether, on the basis of all the evidence, the prosecution has proven the accused's guilt beyond a reasonable doubt. It is crucial to bear in mind that even if you believe that the DNA profiles bore rare similarities, and that only one person in 10 million among the Caucasian population of the United States has such a profile, and even if you are convinced beyond a reasonable doubt that the perpetrator was a Caucasian member of the United States population, that does *not* mean that there is only one chance in 10 million that someone other than the accused was the source of the crime-scene stain. These are two very different matters. The DNA evidence, if you believe it, indicates that the accused has a DNA profile that is present in the crime-scene stain and that is very rare. But even if the profile is very rare, that does not in itself tell you what you need to determine—how probable is it that the accused left the crime-scene stain, which is a factor that may be important in determining how probable it is that the accused committed the crime.

I will try to clarify the point by giving you a couple of examples. Suppose that a person was charged with a burglary and the only evidence against him was that he has red hair, the robber was red-headed, and no more than 6% of the American population is red-headed. Obviously, the probability that someone other than the accused committed the crime is not 6%; rather, given only that evidence, it is virtually certain that someone other than the accused committed the crime, because there are millions of people in this country alone who are red-headed and there is no evidence suggesting that the accused was more likely than any of them to have committed the crime.

> Now, in case that example seems to be fanciful, let me tell you about an actual incident that happened some years ago in England, in which a man was accused of committing a theft on the basis of a DNA test. According to that test, his DNA contained a combination of features that is in the DNA of only one person out of 37 million but that was in the DNA of a stain found at the scene, presumably left by the perpetrator. But that was the *only* substantial evidence against the accused, and other factors made it improbable that he had committed the crime—he lived 200 miles away, and he was severely disabled.[17] One in 37 million means that this combination of features is very rare; if we chose a single person at random we could say that the chance was only one in 37 million that *that* person would have DNA with that combination. But there are 7.5 billion people in the world, and so there are probably about 200 people with that combination. Now, if we did not know about the DNA evidence against this one person, we would have to say that the chance that he committed the crime was infinitesimal; he was, after all, only one person with no particular evidence pointing towards him and a couple of factors, his disability and his distance from the crime, making it highly unlikely that he was the perpetrator. And even after receiving the DNA evidence, even though we would say that this *increased* the chance that he was the perpetrator, we would have to say that the chance remained tiny; it was far more likely that one of the other people in the world with that combination of DNA features committed the crime.
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> Now, don't make the opposite mistake and assume that just because other people in the world might have the characteristic in question, it is no more likely that the accused committed the crime than that any of them did. Let's consider our red-headed suspect again. Let's say that there is substantial evidence against him—he lives near the place of the burglary, and the day after the burglary he attempted to sell a rare object of art that disappeared in the burglary. Now, if we add in the fact that he is red-headed and testimony that the thief, whoever it might be, was red-headed, clearly one would not say he is no more likely than any other redhead to be the thief. However likely it may have appeared, on the basis of the other evidence in the case, that the accused was the thief, the evidence that he and the perpetrator both have red

[17] *Guilty By a Handshake? Crime-Scene DNA Tests May Not Be as Accurate as We Are Led to Believe*, HERALD (Scot. May 1, 2006), http://www.heraldscotland.com/news/12440889.Guilty_by_a_handshake_Crime_scene_DNA_tests_may_not_be_as_accurate_as_we_are_led_to_believe/.

> hair makes that proposition appear substantially more likely.
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> And the significance of that evidence depends on how rare red-headedness is; if, instead of the accused and the thief sharing red-headedness, they shared right-handedness, we would not say that evidence is very significant at all, because *most* people are right-handed. At the other extreme, if the shared characteristic is very rare, then, its significance may be very great when it is put together with other evidence. So let's suppose in the English example that rather than living 200 miles from the scene of the theft the accused lived just down the street, that the evening before the theft he was seen walking back and forth past the house where the theft occurred, and that he was able-bodied rather than severely disabled. Of course, that evidence on its own still leaves it as improbable that the accused was the perpetrator; there may be hundreds of able-bodied people who live about as close or closer, the crime may well have been committed by one of the much larger population that lives further away, and there may be perfectly innocent explanations for why he was walking past the scene of the crime later committed. But now if we add in that the accused has a DNA profile that the perpetrator did, and that only one in 37 million people have that profile, a jury could well conclude that beyond a reasonable doubt the accused committed the crime; true, there may be hundreds of people around the world who have that profile, but a jury could reasonably conclude that beyond a reasonable doubt the perpetrator was the accused, who lives in the immediate vicinity of the crime, had the capacity to commit it, and engaged in behavior suggesting that he was preparing for it.
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> Now, with respect to this case, you may bear in mind that there are approximately 250 million Caucasian people in the United States, so even assuming that the DNA profile in question occurs in only one in 10 million of them, it is reasonable to suppose that there are 25 or so Caucasian people in the United States with that trait. It is your job, members of the jury, to put the DNA evidence together with all the other evidence in the case and determine whether, taking it all into consideration, you believe beyond a reasonable doubt that the accused committed the crime charged in this case.

Obviously, I am not wed to the language of this jury instruction; maybe a very different presentation would be better. But my main point is that whatever the optimal phrasing may be, we in the academic community should work with those controlling the judicial system to ensure that courts

advise juries in the proper treatment of evidence and that neither the parties nor their experts mislead the jury. Would something like this work? I do not know, but it might help—and at least we could say that the jury was not being led astray. That in itself would be a useful advance.