SCIENCE

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LETTERS

DNA Fingerprinting

The present editor of *Science* has more than once attempted to nullify our analysis of scientific issues in the forensic use of DNA polymorphism. First, he demanded that our original article (20 Dec. 1991, p. 1745), peer-reviewed and already in galley proof, be substantially altered and weakened (L. Roberts, 20 Dec. 1991, p. 1721). Then he took the unprecedented step of soliciting a non-peer-reviewed attack on the article that was published in the same issue of *Science* as our article (R. Chakraborty and K. K. Kidd, Perspective, 20 Dec. 1991, p. 1735). Now he has used his privileged access to the editorial column of *Science* to publish an attack of his own (19 Aug., p. 1015).

In his editorial, the editor attributes criticisms of the present forensic use of DNA pattern matching to "a couple of outspoken individuals [who] were less representative of the scientific community than the vast majority of careful scholars." What is his evidence that he speaks for the vast majority of careful scholars? He offers none. Has he made a survey? If he has, does his sample of careful scholars include the professor of clinical genetics who testified under oath that, after one generation of random mating, all linkage disequilibrium between genes on different chromosomes disappears—an error that is cautioned against even in elementary textbooks of population genetics? Does it include the prominent human geneticist who testified under oath that Americans mate at random across ethnic groups within races, when the repeated result of demographic research, discussed in textbooks of sociology, is that there is strong preferential mating by ethnicity within races?

In fact, a study of scientific opinions of DNA testing exists. On 9 July 1991, Charles E. Taylor of the University of California, Los Angeles, submitted an affidavit reporting a survey of 33 persons considered either leaders in the community of population genetics or having other claims to expertise, including members of the National Academy of Sciences (*1*). Taylor classified the opinions of each as critical of the then-current method of calculating the statistical significance of a DNA match, as supportive of the method, or as not committed. Of the total group, 19 were critical: Among the 20 regarded as leaders in population genetics, 12 were critical.

The editor also claims in his editorial that "scientists prominent in casting doubt on DNA use for the prosecution seem to be nowhere in evidence to cast doubt on its use for the defense." There are two things wrong with this statement. First, it is not true (*2*). Second, the statement indicates a basic lack of understanding of the scientific controversy. What issues of population genetics does the editor think are relevant when there is a mismatch? No issues of population genetics are raised when there is mismatch between a defendant's DNA and an evidentiary sample. A mismatch is a mismatch.

The editorial does, however, reinforce our concern with a different important problem—how to achieve reliable standards of general quality control and proficiency testing to minimize sample contamination, mislabeling, and other laboratory errors in the large number of public and private laboratories already engaged in DNA typing. These issues are unlikely to mobilize the forces of either the prosecution or the defense, as the effort would undermine their own use of the results in specific cases. It has therefore been up to the scientific community to demand that the methods be used with standards rigorous enough to attain a reasonable balance between the desire to convict real rapists and murderers and the risk of punishing innocent persons for crimes committed by others.

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References

1. *People* v. *Menephee* (Los Angeles County, No. 003 853, August 1991).
2. *State* v. *Bloom*, 516 N. W. 2d 159 (Minnesota 1994).

If any further proof were necessary as to the need for courts to be skeptical of new forms of "scientific" evidence, that proof would have been provided by Daniel E. Koshland Jr.'s editorial of 19 August. The DNA art has by itself generated a level of smoke and mirrors at which even the lawyers must gaze with awe and envy, and Koshland manages to muddle both the scientific and the legal dimensions even of that.

Koshland notes with irony that "the scientists prominent in casting doubt on DNA use for the prosecution seem to be nowhere

in evidence to cast doubt on its use for the defense." A more fundamental misinterpretation of the nature of DNA evidence could not be imagined, and the fact that Koshland would make such a remark suffices in itself to demonstrate that the level of hyperbole surrounding the subject is getting out of hand.

As I am sure Koshland knows perfectly well, exculpatory DNA evidence typically rests on there being an *in*consistency between the DNA "at the crime scene" and that of the defendant. Absent error, such a finding is determinative: DNA sequences found in a crime scene specimen that differ from those of a defendant simply could not have come from that defendant.

*In*culpatory evidence, on the other hand, rests upon there being total *consistency* between DNA sequences in the crime scene specimens and those from the defendant. However, such a finding merely indicates that the defendant is a member of that class of persons who generate those DNA sequences: there is absolutely no reciprocity here, and while it is easy to show that certain DNA could *not* have come from a particular defendant, and only somewhat more difficult to show that the DNA *could have* come from that defendant, proving that in fact it *did* so come is not at present possible. Once two samples have been shown to be consistent or not, that is as far as the *science* goes. To anyone who employs probability theory seriously, the proof of that statement is almost trivial.

The relevant database shows the frequency at which particular sets of sequences occur. Those data can then be compared to the frequency of occurrence of those sequences within some *other* population. One makes a hypothesis to the effect that the new data may be related somehow to the base data and then tests the validity of that hypothesis using an appropriate distribution function to define acceptable criteria. In forensic DNA analyses, however, that test cannot even be carried out.

Proper statistical analyses require a sample size of at least 30, but in a typical DNA analysis we have the DNA of only one defendant. Presumably, we must then adopt the distribution for small samples, that is, the Student's t test. The value of t is a function of the number of degrees of freedom f, and f in turn is determined from the size of the sample n as $f = n - 1$, so that if $n = 1$, then $f = 0$. But to say that the number of degrees of freedom of some variable is zero is to say that it represents a single event. Statistical calculations have no application to single events: statistical analysis is the study of the behavior of sample populations of meaningful size, and a sample of one is not a sample at all but rather the whole enchilada—everything we may want to know about that specimen we already know.

What the DNA practitioners want to do is give a jury some number for the probability that a DNA specimen taken from some individual will match another DNA specimen taken elsewhere—of course, with ominous implications then to follow. Unfortunately, however, *statistical* theory has no provision for any such process. All that may be fine for the Sunday supplements, but it is not science and should not be presented as such. The problem with the various probability figures one sees is that for forensic purposes, such figures are utterly devoid of scientific meaning. The question of the likelihood that two people could have the same DNA sequences is meaningless with regard to any individual case and will remain so until it is shown beyond a reasonable doubt that individual DNA sequences are *unique*, that is, the relevant number has been shown to be zero. (Calling a DNA sequence a "fingerprint" does not make it so.)

Therefore, contrary to Koshland, I say, "Thank God" for individual judges who are unwilling to be swayed by scientists who have become so enamored of the glamour of DNA analyses (or bubbling over with self-importance) that they are willing to set aside the basic teachings of Statistics 101. To attempt to prove that an individual committed a crime is a serious thing and should not be trivialized by those who not only remain quite innocent of the judicial process, but apparently do not even have enough respect for their own discipline to get it right.

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Response: Hartl and Lewontin make statements that are scientifically inaccurate and accusations that are irrelevant and obfuscating. First, the original article by Lewontin and Hartl was peer-reviewed by a distinguished population geneticist, who found that the authors drew conclusions far beyond their data. Traditionally, *Science* either rejects such articles or asks that the conclusions be more consonant with the data. I therefore offered Lewontin and Hartl two options: either they could make their conclusions more consonant with the data (that is, they could say that there was a very small probability that the tests could give an erroneous result, rather than that DNA testing was invalid) or they could publish their more extreme statements in an opinion piece, rather than as a validated scientific article. Lewontin and Hartl refused both options, so I decided to allow the original article to be published (not "weakened," as they now claim) and asked other

population geneticists to write a Perspective, so that the public would at least know the subject was controversial.

I would do the same if we received a paper about global warming that extrapolated from data indicating gradual warming to a conclusion that we will all burn up in 10 years if we do not stop using fossil fuels. Some *Science* papers affect only a few scientists, and differing views can follow later in a classical tradition. Others, it seems to me, will cause headlines and confusion if a debatable point is exalted, even temporarily, into a fact.

As is now known, some of the statements made by Lewontin and Hartl about population genetics were erroneous. If anything, the genetic diversities of black and Hispanic populations are greater than that of Caucasians, and therefore the calculations by current methods based on a Caucasian population would benefit (but only slightly) an ethnic population.

What has been the result? The use of DNA testing has convicted many, including a gang murderer (the Yee case, in which Lewontin and Hartl testified for the defense); DNA evidence was admitted by the judge, and a jury convicted the defendant. The Federal Bureau of Investigation and Scotland Yard each have a record of not bringing to trial one-third of the accused in rape cases because the DNA evidence exonerates them. In a recent Pennsylvania case, a man accused of rape with high certainty was not arrested because the prosecutor said the DNA evidence showed he was not the criminal. The case was kept open, and eventually the real criminal was found. He bore a strong physical resemblance to the falsely accused individual. A similar case occurred in California. These cases illustrate that, in circumstances of high emotion, objective DNA evidence may be more reliable than eyewitness testimony. More and more courts are accepting DNA evidence, as indeed they should. Paternity cases, identity cases, and criminal cases are being resolved by a method that follows in the tradition of fingerprints as a tool for justice. Scientists who allow their political agendas to overwhelm their scientific objectivity should reflect on the consequences of that choice.

To bolster my statistics with regard to the opinion of scientists, I took a straw poll at a meeting of human genome scientists, experts in DNA use, but not involved in criminal court cases. To the question, "Do you believe DNA procedures by the RLFP [restriction fragment length polymorphism] procedure is accurate enough for use as evidence in court?" 3 of about 600 people voted "No," 15 voted "Don't know enough to judge," and the rest voted "Yes."

Lovell's depiction of statistics seems to me to be so incorrect that I find it difficult to answer him. Statistics are highly relevant to a single event in a courtroom, such as when a plaintiff says a pesticide caused cancer in her child. Such an allegation should be weighed against the fact that 24% of deaths in the United States in 1990 were from cancer. I say, "Thank God" for the increasing number of judges who understand that DNA fingerprinting is a new and powerful tool to absolve the innocent (often in the face of conflicting eyewitness testimony) or to convict the guilty (often in the absence of eyewitness testimony). Fortunately for justice, an increasing number of judges are admitting DNA evidence in courtrooms, and states, such as California, are keeping DNA information about felons.

—Daniel E. Koshland Jr.

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"Real-World Experience" in Chemistry

In his editorial of 6 May (p. 755), "Reorientation of research objectives," Philip H. Abelson quotes John Armstrong, former IBM vice president for research, as saying

> there is little or no encouragement, and a lot of implicit discouragement, for the young person who wants to spend time during graduate school off campus in a setting where technical knowledge is actually used. There is, in short, almost no value assigned to technical breadth or to real-world experience as an essential part of Ph.D. training.

Abelson goes on to urge that "this . . . deficiency . . . be repaired."

The Doctor of Chemistry program at the University of Texas at Dallas, which was designed to prepare students for careers as doctoral-level problem-solvers in chemical and chemical-related industries, is a vital example of an academic program that *does* direct its students toward "real-world experience." Each graduate of the program has spent a mandatory year as a full-time employee in an industrial or government research and development laboratory and has prepared and defended a report on his or her technical accomplishments during that year.

Our program includes a broad chemistry curriculum, with courses emphasizing industrial chemistry, materials science, and problem-solving, and three approximately yearlong research "practica." The program has existed for 12 years and has placed graduates at firms such as BASF, DuPont, Mallinkrodt, United Technologies, Motorola, and Syntex, and at the Los Alamos National Laboratory.