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Some Further Thoughts on Probabilities and Human Hair Comparisons

Publication of two previous papers [*1,2*] on the subject of human hair comparisons has aroused considerable interest. The significance of this research is not in the actual probability numbers found but in the experimental proof of the proposition that macroscopic and microscopic hair comparison is a useful technique and that hair evidence is good evidence. Although the results of the two studies are not inconsistent with those expected by an experienced hair examiner, some further experimental confirmation was attempted. Also, the limitations and use of such results require elaboration. A discussion of the individualization of human hair and the role of this type of work will be given.

Some Further Experiments

Two types of experiment involving macroscopic and microscopic hair comparisons were each carried out three times. The first type was given to three different trainees in this laboratory as a final practical exercise at the end of a one-year training period. Each was given one good representative sample of 80 scalp hairs from one individual. A different individual was chosen in all three cases, all being Caucasian. The trainees were then provided with 100 unknown hairs from 100 individuals, one of which was the one represented by the standard sample. Without being told how many individuals the unknowns were from or how many, if any, of the hairs were supposed to be similar to the standard, the trainees were instructed to compare the unknowns to the standard and report on any similarities.

Two trainees correctly identified one hair and only one hair as being similar to the standard. The third trainee first concluded that there were four hairs similar to the standard. Upon closer examination and consultation with other examiners, he was easily able to identify one of his choices as being incorrect. However, he was still convinced that there were three hairs similar to the standard, the correct one and two others. Examination by the author brought the opinion that one of these two others could be eliminated but that the remaining one was indistinguishable from hairs in the standard. Another experienced examiner then studied the hairs and also concluded that one of the two others could be eliminated. This time, however, it was the one opposite to that picked by the author! All agreed, though, that the correct hair was similar to the standard. It should be noted that the hairs causing confusion in this instance were common and featureless types (for an example of characteristics of a common, featureless hair, see Table 1).

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TABLE 1—*Characteristics of common, featureless hair as chosen for third trial of second experiment.*

Longitudinal View	Cross Section
Length: 54 mm (2 1/8 in.)	Contour: elliptical
Macroscopic appearance: fine and light	Size: medium
Maximum diameter: 0.05 mm	Cuticle: medium
Color: yellow-brown	Color: yellow-brown
Pigment density: medium	Pigment density: medium
Pigment size: fine	Pigment size: medium
Pigment distribution: uniform	Pigment distribution: medium
Cortical texture: medium	Cortical texture: smooth
Treatment: none	
Medulla: absent	
Shaft: constant diameter	
Cuticle: slightly serrated	
Vacuoles: present	
Root: bulb	
Tip: cut within 21 days	

A second type of experiment was conducted by the author. One hundred representative scalp hair samples from one hundred individuals were obtained. From these, an assistant selected one sample at random. From this sample, a single hair was then selected at random. Thus there was one unknown hair to be compared directly to one hundred standard samples. This experiment was then repeated. On both occasions, it was found that the unknown hair was similar to hairs from one standard and only one standard—the correct one. On a third occasion this experiment was repeated. This time the unknown hair was chosen to be a common, featureless type (see Table 1). This hair was found to be similar to two standards, the correct one and one other. An additional experiment with the unknown hair deliberately chosen to be a very unusual type would be trivial.

Kirk [*3*] describes experiments of the same general type as these. His students were able to identify successfully a single hair as being from 1 of 20 samples, all of similar color.

The preceding experiments demonstrate some important points. First, as indicated previously [*2*], certain types of hair from a given body area are more common than others. The probability results previously found are average figures that apply to hairs of average commonness. They should not be applied blindly to all cases. Rather, their use should be tempered by the experience of the examiner. This fact is obvious if we imagine a scalp hair that agrees with hairs from a standard sample in all features, the following being the most notable: 102 cm (40 in.) long, crushed tip, dyed orange, then brown, then black, then bleached twice, with the demarcation lines all being in agreement between the unknowns and the standard. Certainly a 1 in 4500 probability figure would be much too conservative in a case such as this. Now imagine another scalp hair also agreeing with a standard sample in all features, these being as listed in Table 1. In such a case the chances that the unknown could have come from another person would be considerably greater than 1 in 4500. Thus, for most hairs of about average commonness, the probability figures found previously provide a reasonable general estimate, but where hairs can be recognized by the examiner as being at either extreme of commonness, a judgment as to their significance must be made by the examiner. What constitutes a common hair, an average case, or hairs with unusual characteristics must be based on the experience of the examiner. Delineation of such types might be a fruitful area for further research.

Another point is that since everyone's eyes and observation powers are different, hair comparison is still somewhat subjective, as illustrated by the third case of the first experiment.

These experiments also show the importance of experience in hair examination. The work of Kind and Owen [*4*] shows that simply being trained in microscopy is not enough. Special training in hair examination is required to enable a person to obtain the required level of discrimination. A training period in hair examination of at least one year would seem advisable. In subjectivity, thought processes, and a number of other areas [*5*] hair comparison is comparable to handwriting comparison, where the importance of experience has long been recognized.

With two trials in each type of experiment no incorrect assignments of unknown hairs or standards were made. In the third trial of the first experiment incorrect choices occurred because common, featureless hairs were involved. Choosing a common, featureless hair for the third trial of the second experiment helped verify that such hairs are more likely than average to be found similar to a standard obtained from another person.

The preceding points notwithstanding, these experiments offer some verification of the reliability of macroscopic and microscopic hair comparison. Obtaining complete verification for the probability figures previously found would be hopelessly laborious. The important point is that these experiments do not contradict the previous results: when an *experienced* examiner conducts a hair comparison using *all* the macroscopic and microscopic characteristics outlined, if one unknown hair is found to be similar to a representative standard sample obtained from a Caucasian individual, an estimate for an average case of the probabilities of that one hair having originated from someone else would be about 1 in 4500 for scalp hair and 1 in 800 for pubic hair.

Use and Limitation of Results

In the author's experience, the characteristics delineated in the studies [*1,2*] have been worthwhile in comparing hairs. The results have been well accepted in courts and have been used as general estimates for the probabilities involved and as experimental verification of the proposition that hair evidence is good evidence.

When referring to the studies in court, I emphasize that the probability figures are only estimates for an average case. Depending on circumstances, I may then add qualifying statements such as, "In this case, because scalp hairs of Mongoloid racial origin were involved, I would expect the probability of similarity to be somewhat greater than the 1 in 4500 figure" or "Because of the number of hairs involved and the unusual characteristics they possess, the possibility that these hairs could have originated from some person other than the source of the standard sample is extremely remote."

Modification of testimony and reporting is based on the fact that all cases involving hair comparison are not the same. The strength of a finding of similarity depends on such factors as the number of unknowns found to be similar to the standards, the presence of unusual characteristics, the racial origin of the hairs involved, whether or not complete hairs are found, and on the size and reliability of the standard hair sample. Such modification of testimony has been used by other examiners [*5,6*].

In a recent murder case, a man came to be suspected when a clump of approximately 40 scalp hairs was found in his reportedly stolen vehicle. These hairs were compared to those of the murder victim. Both these unknown hairs and the victim's hairs exhibited a wide range of types and characteristics. The unknown hairs were found to be similar to the victim's in all characteristics with the exception of length, the unknown hairs being appreciably longer than the victim's. This difference could be explained by the fact that the sample from the victim was poor, being obtained from just two areas of the scalp. Because the examiner was wary about the discrepancy in length, a standard hair sample from the suspect was requested. This standard sample was found to be similar to the unknown hair in all characteristics and indistinguishable from the victim's hair in all

characteristics except length. The suspect was thus released and another man subsequently confessed to the crime.

This case brings out two points. First, a good standard is important; when more characteristics are available, better comparisons are possible. Second, the fact that several different types of scalp hair were in agreement between the two samples shows that given that an individual has one type of hair, the remaining types of hair on the scalp will not be completely random choices from all the hair types available in the population pool. There is obviously some basis of inheritance for the gross characteristics of a scalp. (A familiar example would be the inheritance of "red" hair.)

In the paper on scalp hair [*1*] the statement was made that if n mutually dissimilar hairs are all found to be similar to those of a given source, the probability of their having originated from another source would be $(1/4500)^n$. This statement is not strictly true, even though in the population studied for that paper no similarities were found in the family groups. The probability would undoubtedly be considerably less than (1/4500) but not quite as small as $(1/4500)^n$. The more similar types of hair there are in agreement between the standard sample and the unknown, the stronger the finding will be, but a straight multiplication of the probabilities is not justified.

Individualization of Hair

In the literature, there is considerable disagreement as to the value of hair evidence. In general, a disparaging view of hair examination has been taken. An example of this is expressed in *Gradwahl's Legal Medicine* [*7*]: "There is nothing about hair comparable to the specificity of fingerprints, and at best the probability of establishing identification from hair is perhaps no greater than the probability of determining identification using the ABO blood group system in blood smears." Whereas it must be conceded that for most cases hair comparison does not, at present, give the specificity of fingerprints, it has certainly been shown [*1,2*] that hair evidence is considerably more specific than identification by ABO blood group systems alone. (The probability that two blood samples selected at random within Great Britain will match with respect to ABO blood group was found to be 0.3423 [*8*].)

The prevailing view of the value of hair evidence has been expressed by Nickolls [*9*]: "If all the points of examination ... correspond then there is a strong presumption that the hair did in fact come from the person, but evidence is never stronger than that"; and by Jones [*10*]: "The probability of identity may grow with every point of resemblance and with the number of hairs available for comparison, but that probability should never be stated as a certainty."

Others [*6,11,12*] have recognized that whereas hair is not generally a basis for positive personal identification, the presence of abnormalities or unusual features or the presence of a large number of different unknown hairs all similar to the standard can lead to a more positive conclusion. This is the view held by the author.

One of the problems that make individualization of hair so difficult is that all the hairs on an individual's scalp (or other body region) are not homogeneous. There is a great variation not only from one hair to the next but also in different locations along the shaft of the same hair. This presents problems not only with comparisons based on macroscopic and microscopic methods but also with trace element analysis.

There are two possible approaches to the individualization of hair. The first is to find a characteristic not only unique to an individual but also homogeneous throughout the scalp or other body region. One possibly fruitful approach to finding such a characteristic would be through biochemical analysis of the amino acid content and pattern of hair.

The second approach to the individualization of hair would be to obtain enough additional variable characteristics of hair so that when they are added to the present macro-

scopic and microscopic characteristics a statistical analysis would conclusively demonstrate in all instances that the chances of two people having similar hairs would be negligible. Parker [*13*] has stated that "the strength of evidence in favor of, or against, the hypothesis that both items come from the same source can be heightened by making as many sets of independent comparisons as possible."

The problem, at present, lies in finding suitable additional characteristics. Although there is basic agreement as to the value of the macroscopic and microscopic characteristics used [*1,2*], other characteristics are either unreliable or controversial.

Physical characteristics such as refractive index, density, scale counts, tensile strength, and electrical properties have been proposed by some workers [*3,14-16*] but have been attacked by others [*17-19*], and the general consensus is that they are of little use in hair comparison.

Although trace element analysis was at one time thought to be the key to the individualization of hair, it is now realized that such an approach has serious limitations and problems [*20,21*]. It is now felt that the greatest value of this method is through simultaneous multielement analysis to determine individuals with abnormally high or low concentrations of certain elements. These abnormalities could be used as additional identifying characteristics. An interesting variation of trace element analysis whereby the pattern of uptake of certain elements is characterized [*22*] may have potential for providing additional characteristics.

Other instrumental methods of analysis, including pyrolysis gas chromatography [*23*] and disk electrophoresis [*24*], have been attempted on hair with little success at finding individualizing characteristics.

Successful ABO blood grouping of single hairs has been claimed [*25*], but other examiners, [*18*], including the author, have not been able to obtain reliable results with this method. Should a more reliable technique be developed, a useful additional characteristic for hair comparison would be provided.

The following techniques that have been proposed also appear to have good potential for providing additional characteristics for hair comparison: sex determination [*26*], identification of hair sprays and other cosmetic treatments [*17*],[2] photoluminescence [*27*], and the use of the scanning electron microscope to show surface damage [*28*] and abnormalities [*29*].

Some or all of these techniques together with others not yet developed could provide enough additional characteristics such that, when they are added to the present characteristics, a statistical analysis could show that the chances of an unknown hair originating from more than one source would be negligible. Hair evidence would then become as useful and widespread as fingerprint evidence.

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