

James Robertson,¹ Ph.D.
and Colin Graeme Girdwood Aitken,² Ph.D.

The Value of Microscopic Features in the Examination of Human Head Hairs: Analysis of Comments Contained in Questionnaire Returns

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ABSTRACT: Comments received in response to a questionnaire seeking opinion about hair examination have been considered. The questionnaire was in two parts: the first was concerned with the description of microscopic features and the second with the use of numerical features and data sheets in hair examinations. The same format is used to present a synopsis of the many individual comments and suggestions contained in questionnaire returns. It is argued that a hair examination form can contribute to more effective hair examinations although not replacing direct side-by-side comparisons. A hair examination form is presented with recommendations for its use.

KEYWORDS: forensic science, hair, microscopy, protocols

Background

The background to this study has been discussed in Ref 1 in which the statistical analysis of the answers to "closed form" questions were considered. Participants were asked to agree or disagree with the number of categories used to describe features of hair. Thus, while respondents might agree that three categories adequately defined, for example, cross-sectional shape, they might have defined these in a different way, if indeed at all! Space was provided in the questionnaire for additional comments to overcome this limitation and it is these that are considered here. A "protocol" is developed for hair examination which includes the use of a hair examination form.

Analysis of Comments

The questionnaire was designed in two parts [1], and comments relating to each will be considered separately.

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¹Lecturer, Forensic Science Unit, University of Strathclyde, Royal College, Glasgow, U.K.; now, forensic scientist, Forensic Science Centre, Adelaide, South Australia.

²Lecturer, Department of Statistics, University of Edinburgh, Edinburgh, U.K.

Individual Features

The comments received dealt with two main points.

Subjective Nature of Hair Features—The statistical analysis of questionnaire returns showed that with respondents from the United Kingdom (UK) there was a trend towards fewer categories for most hair features, but more categories with respondents from North America (NA). This is an oversimplification as opinion within NA also varied markedly. Those respondents who wanted fewer categories in many instances justified this by arguing that the use of too many subdivisions of microscopic features resulted in a subjective assessment from the analyst. Those who opted for more categories argued that in limiting the subdivisions the discrimination inherent in hairs would be lost. It may be that differences in the (perceived) ability of examiners to discriminate between categories of hair features influence the opinions of respondents in relation to this question. Microscopic features are continuous variables and any attempt to produce discontinuous, segmented units has limitations.

If the "true" value of microscopic features is to be assessed, studies are required aimed at measuring the ability of analysts to record objectively such data. One of us [2] has defined objectivity of nonnumerical microscopic features of hair as:

- (1) the ability of different analysts to reach the same decision, and
- (2) the ability of one analyst to reach the same decision given the same feature or hair to examine on a number of occasions.

The Need to Define and Standardize Terminology—This is a logical extension of the first point. The objective assessment of microscopic features would be improved by clearly defining these features. It was obvious from the questionnaire returns that many respondents described the same feature in different ways illustrating the need to standardize the nomenclature or terminology used by hair examiners. Several respondents used or suggested the use of "standard" slides of hairs to aid in classifying hair color and pigmentation. The production of a photographic atlas of hair features supported by adequate definitions and descriptions of these features was also proposed. Such an atlas is currently being produced as the results of the efforts of the North American Committee for forensic science examination of human hair [3].

Variation

Many, if not all, respondents raised the question of how to record the variation along the length of the hair shaft in hair examinations. It may have been a fault of the questionnaire design that it was not clear that the main purpose was to investigate the choice of features and not how they varied. Variation within a single hair, between hairs within an individual, and between individuals is the whole crux of hair examination.

Choice of Features

Another limitation imposed by the questionnaire was that it was aimed at the examination of Caucasian hair only. This is clearly an artificial concept in casework situations as the population of most countries is of mixed ethnic origin. Some microscopic features may be of more value for non-Caucasian hairs. The choice of features for inclusion in the questionnaire reflected in part (1) the views of the authors, (2) the limitation to those features thought to be of value in Caucasian hair examination, and (3) the role of the authors as "devil's advocates."

Few additional features were suggested by UK respondents while a wide range of features were suggested by NA respondents. This may reflect the wider ethnic base of NA or it may mean that hair examiners in NA do in fact examine a broader range of features for all hairs than their UK counterparts. The underlying reasons for this difference are less important than consideration of what features are of potential value in hair examination.

Table 1 gives a summary list of the features which form the basis of the hair examination

TABLE 1—*Hair examination form—feature list.*

MACROSCOPIC FEATURES		
Length		centimetres
Shaft profile		straight wavy curly peppercorn
Color		colorless yellow brown reddish black
Root end		root not present club root root without sheath root with sheath
Tip end		natural taper cut rounded frayed or abraided split crushed or broken singed
MICROSCOPIC FEATURES		
Pigment	density	absent light medium heavy opaque
	distribution (across shaft)	uniform/even towards medulla towards cuticle to one side
	aggregate shape	streaked clumped—oval round
	granule shape	round oval/oblong
	aggregate size	fine medium coarse
	granule size	fine medium coarse
Medulla	distribution	none medulla > space medulla < space continuous
	type	opaque translucent
Cortical fusi	present	
Cortical texture		not visible visible or coarse
Cuticle	thickness, μm	
	color outer margin	smooth serrated ragged cracked looped
Scales	distal margin shape	smooth crenate/rippled serrated

form presented in the Appendix. In arriving at the choice of these features, an attempt has been made to achieve a measure of common ground between respondents. This list is not intended to be all-embracing, but to provide a framework which can be modified by research or personal experience and preference.

Features may be grouped into those which are macroscopic (often observed with the aid of a stereo microscope) and microscopic features. Hair color can be used to illustrate this division. Given a single hair or a group of hairs, color may be assessed using a low magnification stereo microscope. The questionnaire included *nine* subcategories and many respondents felt that this was still too limited to describe adequately the almost continuous spectrum of color in human hair.

The question that needs to be asked is whether or not such fine subdivision achieves the aim of hair examination? What indeed is the aim of hair examination? We would argue that it is to provide a complete and objective description of the sample, be it a single hair or a group of hairs. Thus, there may be a conflict between the complete and objective elements. Any classification of color (or any feature) must balance these two elements. The feature list in Table 1 gives only a small number of BASIC colors or hues, but should be further refined by the use of SHADE, light, mid or dark. A final point with respect to color is the need to standardize examination conditions. If a color is observed that cannot be adequately described by the listed colors then this can be noted.

The color assessed macroscopically can be explained at the anatomical level from the pigment present in the cortex and the degree of medullation present in the hair shaft. These two features may then be defined at the microscopic level.

With respect to the remaining macroscopic features, shaft profile and the condition of the root and tip ends, the subcategories may not be exhaustive but should include most of the commonly occurring types.

The classification of pigment given in Table 1 differs considerably from that of the questionnaire. It seems clear from the NA answers that insufficient emphasis was placed on describing the individual pigment particles or granules as compared to accumulations, groups or aggregates of these. Thus, Table 1 attempts to describe *aggregate and granule shape and size*. At present, the number of subdivisions may not satisfy all examiners while it may encourage others to consider pigment features in a more precise manner.

The definition of medulla type also varies greatly from that given in the questionnaire. There seems a clear need to describe two aspects of the medulla, DISTRIBUTION and TYPE. Only four subcategories are presented for medulla distribution which should take into account all visible medulla whether clear (translucent) or dark (opaque).

In addition to the features given in the questionnaire, features associated with the cortex, scales, and the cuticle are included in Table 1. Few respondents from the UK or Europe suggested their use, while many replies from NA respondents stressed their use. As with hair color, the definition of these features and the subcategories included may not satisfy some examiners while alerting others to their potential value.

No feature dealing with cross sections is included as most respondents did not include sectioning in their examinations and expressed doubts about whether any additional information would be gained. However, those respondents who do use cross sections thought them to be extremely valuable. It may be that the determining factor is the quality of section produced.

With respect to numerical features most examiners felt that they were of limited value and certainly less useful than the less "objective" nonnumerical features. Nevertheless, no examination would be complete without the length of hair shaft being measured (where possible!) and its diameter measured at different parts along the hair shaft.

Use of Data Sheets

Many respondents had reservations about the use of data sheets, but few were totally opposed to their use. Most expressed the hope that this study would lead to the production of a

better and more workable sheet or hair examination form. The reservations expressed by respondents fell into three broad areas.

Construction of the Data Sheet—A large number of data sheets used in forensic science laboratories were sent to the authors. These varied in complexity from single sheets with a few lines drawn, to complex multifeature punched index cards. Many examiners were not satisfied with their forms finding them either *too* detailed or *not* detailed enough!

One person pointed out the difficulty in using his data sheet for both single hairs and a known (control) sample. The major problem associated with the use of detailed data sheets was the time necessary to complete them when, at the end of the day, they could not be used to show whether or not two hairs could have had a common origin. However, the impression was given by some that they were not willing to spend this time completing a data sheet because they considered hair to have such limited evidential value.

There is a fundamental need to define the part to be played by such a form in the examination of hair. Clearly some examiners consider that the form should be capable of holding sufficient detail to show “identity” of hairs (with or without comparison microscopy?). This could be an achievable aim, but is it desirable? In our opinion, an examination form should play only a minor role in the COMPARISON PROCESS but an important role in the DESCRIPTIVE PROCESS. These two aspects need to be separated and clearly understood. This point will be further emphasized in the concluding section.

Philosophical Objectives—Many respondents felt that by using a data sheet nonscientists (lawyers?) place too great an emphasis on the information contained in the sheet and not on the use of the comparison microscope. Filling in categories for microscopic features, it was felt would imply these features were objective. Others felt that the data sheet was self-limiting and could not adequately represent the continuous variables found in hair. The major concern expressed was that a conclusion regarding the comparability of two hairs could only be made by comparison microscopy.

Problems with Use in Court—A small number of respondents expressed reservations about what would happen if data sheets were available to the defense, who might make spurious use of them either by intent or through a lack of knowledge. Of course this argument could equally apply to the prosecution and displays apparent bias on the part of some respondents. Misuse or abuse of scientific data is not confined to hair examination and in this context is more a problem of the design of the data sheet. It is the job of the forensic scientist to explain to the court what significance and limitations should be placed on the “facts” being presented.

Many respondents expressed the view that there were positive aspects to the use of data sheets, namely, that they:

- (1) encourage systematic observation,
- (2) produce a written record of the examination, and
- (3) aid in the training of hair examiners.

However, one respondent went so far as to state:

the information that is observed is tabulated in the examiner’s mind and need not be placed on paper.

In the opinion of the authors, this is a dangerous and ill-conceived stance to adopt, but it does help to emphasize the less outspoken but implied view of many respondents that they do not require extensive, detailed notes of hair examinations.

There are several reasons why this is open to criticism. A practising forensic scientist will carry out a large number of cases every year and there will often be a delay of months before the results are presented as evidence in court. It is difficult to conceive of anyone retaining fine detail of every case under these circumstances. Further, where detailed notes are not taken, there is no way in which the results or observations of the examiner can be checked as part of a quality assurance program or by a defense scientist.

No forensic scientist would comment on “matching” chromatographic data without includ-

ing the relevant charts and experimental details in case notes, yet some hair examiners would appear to believe it sufficient to comment that hairs give a positive comparison without any of the reasons that support that conclusion!

In commenting on the use of a hair data sheet or examination form, the use of these has to be clearly separated from the comparison process. Many of the criticisms of data sheets stem from the belief that their use will in some way preempt the comparison process, or that the data sheet must be sufficiently comprehensive to include every minute detail.

A hair examination form is presented in the Appendix, which is an attempt to meet some of the practical and philosophical problems raised by this questionnaire. Feature selection has been aimed at achieving a workable balance between the various conflicting viewpoints while *not only* is space left for further comments and description, but this is positively encouraged. An examination form should not be a "straightjacket" constraining the examiner but rather should guide and assist the examination process.

This form can be used for single hairs or for many hairs. It could be readily modified to meet personal preferences and could be placed on a computer program which would reduce the time taken to complete examinations.

Conclusions

The questionnaire has without doubt encouraged many hair examiners to give serious thought to the hair examination process. If it achieves nothing else, this, in itself, has been worthwhile. It is the opinion of the authors that a well designed hair examination form has a place as part of the hair examination protocol. However, the value of its role is not to reduce the significance of side-by-side hair comparisons. This is the only effective method of comparing individual features and the pattern of these features within the whole hair. Rather, its value lies in encouraging a systematic, documented examination. Used in conjunction with an atlas of hair features, it would help to improve the objectivity of hair examinations and could lead to the collection of data giving the frequency of various features in a population. This could enable the hair examiner to give an opinion as to how common or rare a hair type is in that population. This is likely to produce a much more conservative estimate of the probative value of hair evidence than the approach of Gaudette [4,5]. The potential discrimination offered by the frequency approach is constrained by the number of features and subcategories in the examination form, and in an effort to maintain or improve the objective assessment of these features, subcategories may have to be limited.

There is a clear need for an extensive research program to evaluate the microscopic features of hair from a forensic science standpoint, to define and standardize nomenclature on an international basis, and to evaluate properly the probative value of hair evidence.

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APPENDIX

A Draft Protocol and Hair Examination Form

Protocol for Hair Examination and Instructions for Use of Hair Form

1. The KNOWN (control) sample should be examined using a stereo microscope; the standardization of illumination conditions is important for comparative examinations. Six (or more) hairs should be selected to represent fairly the range of hair lengths, colors present, and then other microscopic features recorded.

2. Choice of mountant will affect the features observed: as most of the microscopic features are found in the cortex, the mountant should have a refractive index which will give sufficient contrast.

3. It is possible to include cross-sectioning in the protocol for hair examination. Hairs may be sectioned at a set distance from the root, giving only one section per hair, or by folding over the hair and sectioning the shaft at various points. Although some clarification of features observed in the longitudinal plane may be achieved, it is debatable whether the extra work is justifiable. The value of cross-sectional shape is unclear.

4. It is not always possible to describe adequately the features or variation present in a single hair using the discontinuous classifications used in this form. It is important to use a combination of *written notes and the features listed*.

5. After completing an examination of the known hair sample(s), each questioned hair should be examined separately in precisely the same way as with the known hair sample(s).

6. Each questioned hair **MUST** be compared with one or more known hairs, selected on the basis of possessing similar features to the questioned hair.

It is important to realize that it does not follow that two hairs with the same features recorded on the form cannot be distinguished. The final decision on whether questioned and known hairs could have had a common origin must only be made after the hairs have been compared side by side using a comparison microscope.

7. It is unlikely that a questioned and known hair will be indistinguishable for all features **ALONG THEIR ENTIRE LENGTH**. To conclude two hairs could have had a common origin, these hairs should show the same degree of variation and be indistinguishable at a minimum of one point along their length.

This form is based on a questionnaire survey carried out in 1982–1983, but the final choice and categorization of features reflect the personal choice and opinions of the authors.

MACROSCOPIC FEATURES

HAIR NUMBER		/1	/2	/3	/4	/5	/6
LENGTH	CM						
SHAFT PROFILE	STRAIGHT						
	WAVY						
	CURLY						
	PEPPERCORN						
COLOUR ¹	COLOURLESS						
	YELLOW						
	BROWN						
	REDDISH						
	BLACK						
ROOT	ABSENT						
	CLUB ROOT (bulbous)						
	RIBBON						
	no outer sheath						
TIP	OUTER SHEATH PRESENT						
	NATURAL TAPER						
	CUT						
	ROUNDED						
	FRAYED OR A BRAIDED						
	SPLIT CRUSHED OR BROKEN						
	SINGED						

GENERAL DESCRIPTION AND COMMENTS

1a Assessed with a stereo microscope using standardised illumination
 b Basic colour to be qualified by shade or depth of colour, light (L), mid (M) or dark (D)
 c Artificial colouring: note and, if possible, measure distance from root where colour changes.

MICROSCOPIC FEATURES

FEATURE	HAIR NUMBER	/1		/2		/3		/4		/5		/6	
		R	T	R	T	R	T	R	T	R	T	R	T
SHAFT DIAMETER μ													
PIGMENT DENSITY	NONE												
	LIGHT												
	MEDIUM												
	HEAVY												
	OPAQUE												
PIGMENT DISTRIBUTION (across hair shaft)	UNIFORM												
	TOWARDS MEDULLA												
	TOWARDS CUTICLE												
	TO ONE SIDE												
PIGMENT AGGREGATE SHAPE	STREAKED												
	CLUMPED												
	OVAL												
	ROUND												
PIGMENT GRANULE SHAPE	ROUND												
	OVAL/OBLONG												
PIGMENT AGGREGATE SIZE	FINE												
	MEDIUM												
	COARSE												
PIGMENT GRANULE SIZE	FINE												
	MEDIUM												
	COARSE												
MEDULLA DISTRIBUTION	NONE												
	MEDULLA SPACE <												
	MEDULLA SPACE >												
	CONTINUOUS												
MEDULLA TYPE	OPAQUE												
	TRANSLUCENT												
CORTICAL FUSI ²													
CORTICAL TEXTURE	NOT VISIBLE OR SMOOTH												
	VISIBLE OR COARSE												
CUTICLE THICKNESS μ													
	COLOUR												
CUTICLE OUTER MARGIN	SMOOTH												
	SERRATED												
	RAGGED												
	CRACKED												
	LOOPED												
SCALES DISTAL MARGIN SHAPE	SMOOTH												
	CRENATE /RIPPLED												
	SERRATED												

2 CORTICAL FUSI ARE MOST OFTEN FOUND TOWARDS THE ROOT END OF THE HAIR SHAFT; WHERE PRESENT THEIR SHAPE, SIZE AND DISTRIBUTION BOTH ALONG AND ACROSS THE SHAFT MAY HAVE SOME VALUE WHEN USED AS COMPARATIVE FEATURES.

GENERAL DESCRIPTION AND COMMENTS³

³ NOTE PRESENCE OF PARASITES OR DISEASE CONDITION OF HAIR

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Address requests for reprints or additional information to
James Robertson, Ph.D.
Forensic Science Centre
21, Divett Place
Adelaide, 5000, South Australia