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Author: Silvana R. Tridico M.M.Houck K. Paul Kirkbride
M.E. Smith B.C. Yates



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1 TITLE PAGE:

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3 **Morphological Identification of Animal Hairs: Myths and Misconceptions, Possibilities and**

4 **Pitfalls**

5 **Silvana R. Tridico^{a,*}, M.M.Houck^b, K. Paul Kirkbride^c, M.E. Smith^d, B.C. Yates^d**

6 ^a *Australian Wildlife Forensic Laboratory, Veterinary and Life Sciences, Murdoch University,*
7 *Perth, Western Australia, 6150, Australia*

8

9 ^b *Department of Forensic Sciences, Consolidated Forensic Laboratory, 401 E Street SW*
10 *Washington, D.C. 20024, USA e mail: Max.Houck@DC.gov*

11

12 ^c *School of Chemical and Physical Sciences, Flinders University, GPO Box 2100, Adelaide, South*
13 *Australia, 5001, e mail: paul.kirkbride@flinders.edu.au*

14

15 ^d *Forensic Scientist – Morphology National Fish and Wildlife Forensics Laboratory, 1490 East*
16 *Main Street, Ashland, Oregon 97520, USA e mails: cookie_smith@fws.gov &*
17 *bonnie_yates@fws.gov*

18

19 * Corresponding author. Tel: +61 8 82785731

20 *e mail: silvanatridico@yahoo.com*

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22 **Morphological Identification of Animal Hairs: Myths and Misconceptions, Possibilities and**

23 **Pitfalls**

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26 **HIGHLIGHTS**

27 1. We compare and contrast skill sets required for practitioners conducting human hair
28 comparative analyses with those required attributing animal hairs to a particular taxon.

29 2. We discuss the consequences of ill trained or inexperienced practitioners attempting to
30 identify animal hairs in the context of myths and misconceptions.

31 3. We will discuss the future of the microscopical identification of animal hairs in the context
32 of SWGWILD

33 We propose recommendations that should be adhered to in order to ensure quality practices
34 in relation to the identification of animal hair.

35

36

37 **ABSTRACT**

38 The examination of hair collected from crime scenes is an important and highly informative
39 discipline relevant to many forensic investigations. However, the forensic identification of
40 animal (non-human) hairs requires different skill sets and competencies to those required
41 for human hair comparisons. The aim of this is paper is not only to highlight the intrinsic
42 differences between forensic human hair comparison and forensic animal hair identification,
43 but also discuss the utility and reliability of the two in the context of possibilities and pitfalls. It
44 also addresses and dispels some of the more popular myths and misconceptions surrounding
45 the microscopical examination of animal hairs. Furthermore, future directions of this
46 discipline are explored through the proposal of recommendations for minimum standards
47 for the morphological identification of animal hairs and the significance of the newly
48 developed guidelines by SWGWILD is discussed.

49 Keywords: animal hairs; human hairs; microscopy; morphology; SWGWILD; wildlife forensic

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57 Western Australia 6150) to the paper

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61 **1. Introduction**

62 The morphological identification of animal (non-human) hairs (MIAH) is based on fundamental
63 aspects of microscopy, biology, and zoology. The purpose of MIAH is to categorize the animal
64 source of an unknown hair sample to a particular taxon based on well-defined, genetically-based
65 features that are characteristic to that group. The breadth of knowledge required to identify
66 mammalian hairs from all potential taxa is extensive but may be relatively simple in certain
67 contexts, for example identification of mammal hairs as encountered in biological fieldwork, in
68 museum curation, or in the textile industry. In contrast, the forensic examination of hair involves
69 knowing not only the range of expression of mammalian hairs within taxa, but also being aware of
70 other structures that may resemble hairs, such as man-made wig fibers and faux fur fibers, insect
71 seta, and plant tendrils. The forensic context is thus wider and more complicated than a controlled
72 mammalian orientation.

73 This complexity is compounded because forensic hair examiners typically are examiners of human
74 hair. Unlike MIAH, the human hair practitioner is dealing with hairs from a single species, *Homo*
75 *sapiens*, and answering a quite different series of questions which may include (but not limited to):

76 1. Is it a human hair?

- 77 2. From what area of the body did it originate?
- 78 3. Is there damage, disease or treatment evident in the hair?
- 79 4. Are the hairs suitable for forensic nuclear DNA profiling?
- 80 5. Does the hair contain sufficient information for comparison to a putative human source or
- 81 sources?
- 82 6. Could the hair have originated from one of those sources?
- 83 7. What is the broad ethnic origin of the donor of the hairs? (i.e., Caucasian, Mongoloid or
- 84 African)

85 Although questions 1-3 may also be relevant to anthropology, questions 4 –7 are purely forensic in

86 nature and address a concept specific to forensic methods, i.e. source attribution. In fact,

87 categorization and source attribution represent the core and enduring questions asked of a forensic

88 investigation: “What is this material?” “Where did it come from?” and “Does it confirm or reject

89 associations between people, places, and things involved in criminal activities”. The first part,

90 categorization or identification, is common enough among sciences; what sets forensic science

91 apart is its core intention of sourcing where the identified item came from (the victim, suspect,

92 their environments or the scene).

93

94 The composition and origins of materials lend themselves to a greater or lesser specificity of

95 sourcing. Hairs, because of their complex matrix and variable expressivity, are limited by their

96 “intra sample variations (which) can be nearly as large as variations between certain samples from

97 different sources...the results of a hair comparison (are) far less than certain” (1). The process of

98 human hair comparison is widely considered as fundamentally ‘subjective’ in the context that

99 results and conclusions are not quantifiable but based on opinion. This practice is not unique to

100 forensic analyses; it is also relevant in areas of the medical profession such as histology (e.g.

101 identifying cancer cells) and anthropology/paleontology (e.g. identification of human/animal
102 remains on the basis of bone or teeth morphology).

103 Typically, three conclusions can be drawn from a human hair comparison, given suitable samples:

- 104 1. The questioned hair exhibits the same microscopical characteristics as the known sample
105 and therefore could have come from the person from which the known was taken,
- 106 2. The questioned hair exhibits different microscopical characteristics as the known sample
107 and therefore could not have come from the person from which the known was taken,
- 108 3. The questioned hair exhibits both similarities with, and differences to, the known sample
109 and therefore no conclusion can be drawn as to the source of the questioned sample.

110

111 In some instances positive associations deduced from this comparative process have been afforded
112 more probative value than is scientifically warranted resulting in individuals being wrongfully
113 incarcerated (2). As a consequence, criticism has been leveled at forensic human hair comparison,
114 which may tarnish related or similar disciplines, especially MIAH. However, there is a
115 fundamental difference between comparative examinations between human hairs to infer an
116 association to a particular individual (sourcing) and MIAH, which is an exercise in taxonomy to
117 identify an animal hair to a particular taxon and not to a particular animal. Therefore, criticisms
118 leveled at the former are not relevant to the latter.

119

120 This paper is primarily aimed at raising awareness levels of what can go wrong for inexperienced,
121 unwary or inadequately trained practitioners attempting to microscopically identify animal hair.

122 The paper also discusses the future of MIAH in the context of accreditation of the discipline and its
123 practitioners.

124 **2. Morphological Identification of Animal Hairs**

125 All mammalian hair is composed of the protein keratin. Mammalian hairs are all similar in their

126 chemical composition and major structural features but they do differ to a greater or lesser extent
127 in morphology at varying taxonomic levels. Mammalian hair consists of three layers: an outermost
128 cuticle, an inner cortex, and a central core or medulla as illustrated in Figure 1. Mammalian hairs
129 bear morphological features characteristic for a particular taxon that may be phylogenetic in origin
130 or functionally derived, these are:

- 131 1. the configuration of cells in the medullae of guard hairs,
- 132 2. cuticle scale patterns,
- 133 3. transverse cross-sectional shapes.

134 Additionally, mammals exhibit somatic variation in hair morphology that must be taken into
135 consideration for taxonomic identification. Whilst the examination of animal hairs takes into
136 consideration gross morphological features such as color (banded or uniform), length and general
137 profile, these are not, in general, taxon specific. However, these features may assist in excluding
138 animals from a particular taxon as sources of the hair in question if a number of taxa share similar
139 microscopical morphological characteristics.

140

141 **3. Myths and Misconceptions**

142 Several popular myths and misconceptions exist regarding MIAH that demonstrate ‘a little
143 knowledge is a dangerous thing’ when exercised without any competence in MIAH.

144 *3.1 Myth: Cat (Felis catus) and Dog (Canis lupus familiaris) hairs can be reliably identified solely*
145 *on root shapes*

146 Hairs from cats and dogs are undoubtedly the most commonly encountered animal hairs in forensic
147 (crimes against the person) examinations. There are a number of forensic publications that state
148 that the identification of these two species may be effected solely on the basis of their root shapes
149 (3, 4). It is generally accepted in the scientific community that hairs from these two species can be
150 distinguished, and identified, on the basis of the shape of their hair roots, i.e., dog hairs exhibit
151 spade-shaped roots, and cat roots are fibrillated (Figure 2). However, both of these root shapes can

152 occur in both species (5) and other species. In order to effect an accurate identification, and one
153 that withstands scientific scrutiny, the examiner must consider details of the medulla and scale
154 pattern throughout the length of guard hairs in order to distinguish between each of these species -
155 not solely the root shapes. Furthermore, the examiner must query the aggregate morphological
156 characteristics in order to consider what other animals might exhibit similar features in all aspects,
157 i.e. medulla pattern, cuticle pattern, and in some instances, cross-sectional shapes.

158 Some early work by Peabody et al (6) indicated that medullary index (i.e. the ratio of the medulla
159 diameter to the hair diameter) could be used as a basis for discriminating domestic cat (*Felis catus*)
160 hairs from dog (*Canis lupus familiaris*) hairs. Although this work was original and important, we
161 believe that it is of limited forensic value. Identifications were effected by comparing data derived
162 from reference hairs of unknown body origin with questioned hairs of unknown body origin. We
163 believe a more scientifically valid approach would have been to produce different data sets derived
164 from hairs from known body areas, for comparison with data derived from the questioned hairs
165 from unknown body areas. This is because morphological characteristics of animal hair varies in
166 relation to somatic origin i.e. body area (7). In addition, Peabody et al (6) attempted to corroborate
167 their quantitative findings with scale pattern analysis. Unfortunately these authors compared scale
168 patterns from what they believed to be domestic cat hairs (*Felis catus*) (based on their medullary
169 index) with the images of cat hairs produced by Appleyard (8). However, the cat hairs Appleyard
170 (8) examined came from an African Wild Cat (*Felis ocreata catus*) and not a domestic cat (*Felis*
171 *catus*). Each of these felid species exhibit different scale patterns as illustrated in Appleyard (8)
172 and Brunner and Coman (7).

173 3.2 Misconception: Pig (*Sus scrofa*) hairs may be mistaken for human hairs

174 Not infrequently forensic scientists need to identify hairs recovered from environments such as
175 forests, beaches, or caves to determine whether the hairs are human or animal in origin. If human,
176 authorities may be looking for an injured or deceased person and law enforcement personnel need

177 a timely, accurate identification of these hairs in order to determine an appropriate course of
178 action.

179 Whilst it is accepted that pigskin is commonly used as a surrogate for human skin, and pig corpses
180 are used in taphonomic studies *in lieu* of human cadavers, the hairs of these two species are
181 absolutely distinguishable as demonstrated in Figure 3, which depicts features exhibited in dorsal
182 hairs of adult pigs. An additional feature characteristic of adult porcine hairs is that the tips of
183 pig guard hairs are split (commonly referred to as 'flagged') in most instances.

184 This myth highlights the necessity of forensic animal hair examiners to be competent and capable
185 of correctly identifying animal hairs from wild and 'domesticated' fauna in their particular
186 geographic location.

187

188 *3.3 Misconception: Scanning Electron Microscopy (SEM) is more effective than Transmitted Light*
189 *Microscopy (TLM) in animal hair identification*

190 It is widely espoused (e.g. (9-13)) that by using high magnification and sophisticated digital
191 microscopy more details will be revealed that will provide more power of observation and
192 therefore more exactitude in MIAH - this is unfounded. Although SEM can certainly deliver high
193 magnification and depth of field (much higher than transmitted light microscopy), it is a
194 monochromatic, surface-imaging technique that cannot provide details of color or internal
195 structure. As noted by Rowe (14) '...SEM for hair examinations is limited because most the
196 morphological features used to identify species of animal from which the hair originated and used
197 to compare evidentiary and exemplar hairs are within the hair, not on its surface'.

198 Transmitted light microscopy is the recommended and most widely used method for examining
199 internal features and cuticle scale pattern along the entire length of the hair, as well as hair cross-
200 sectional morphology. This provides the examiner with a comprehensive view of the specimen

201 and allows study of all available taxonomic features that may be critical to effect an accurate
202 identification.

203

204 *3.4 Myth: Polar bear (Ursus maritimus) hairs are hollow*

205 The most prevalent and widely cited myth, which appears to be universally accepted on the
206 Internet¹ and in peer-reviewed literature (15, 16), is that polar bear hairs are hollow. Polar bear
207 hairs have been described by Morioka (17) as having a shaft that resembles an ‘end-capped straw,’
208 implying that the shaft is like a hollow tube. Furthermore, Morioka (17) also states that polar bear
209 hairs lack medullae.

210 Each of these assertions is demonstrably incorrect as shown in (Figure 4). The medulla or core of
211 the hair shaft is composed of air filled cells and vacuoles, which, under transmitted light appears
212 dark; however, if the hair shaft integrity is compromised, mounting medium may seep into the hair
213 and fill the medulla cells and vacuoles. The result is that the entire hair becomes translucent and
214 apparently devoid of a medulla using transmitted light microscopy.

215 It is possible that inexperienced researchers, concluding that polar bears as hollow, may have
216 based this observation on hairs with a cleared medullae (Figure 4). However, as Morioka (17) did
217 not provide the images from which he derived his conclusion it is impossible to ascertain what is
218 was that led him to his “hollow hair” conclusion.

219

220 **4. Possibilities in MIAH**

221 Assuming a competent practitioner conducts the identification process, the taxon level to which the
222 animal hair in question can be attributed is dependent on the following criteria

223 1. The hair type

224 2. Condition of the hairs

¹ Using Google, a search of the Internet using the string ‘polar bear hair hollow’ returned in excess of 450,000 ‘hits’ that supported this premise.

225 3. Availability of reference hairs from known, vouchered specimens for comparison with the
226 morphological characteristics from the questioned hair

227 As discussed in Section 1, guard hairs are recognized as the hair types that contain the most
228 diagnostic features upon which a microscopical identification may be made. If the condition of the
229 hair in question is such that insufficient morphological characteristics are present (e.g. short,
230 broken hair fragments or hairs that have been degraded by environmental processes) identification
231 may only be possible to a higher taxonomic level such as Order, rather than at a lower level such
232 as Family or Genus.

233 Confirmation of the identification necessitates the comparison of the characteristics exhibited by
234 the questioned hair with relevant hair(s) from a vouchered animal reference specimen.

235 MIAH cannot attribute the source of a questioned hair to an individual animal; however, some
236 studies suggest limited associations may be possible (18, 19).

237

238 **5. Pitfalls**

239 This section discusses common pitfalls witnessed by the authors, either through reviewing
240 literature or reviewing work conducted by inexperienced or inadequately trained animal hair
241 examiners.

242 *5.1 Training*

243 MIAH, like any other scientific discipline, is only as good as its practitioners, the equipment, and
244 the reference materials they use. Pertaining to practitioners, Bisbing and Houck state: “Training
245 and qualification of forensic hair examiners is crucial to the quality and reliability of forensic hair
246 examinations. Many of the weaknesses in forensic hair examinations...are a result of inadequate
247 training of forensic hair examiners and a lack of understanding about the fundamental nature of the
248 examination of hairs”(20). Although this was written in relation to human hair examinations, the

249 tenet is equally applicable to MIAH. A practitioner seeking to identify an animal hair needs to
250 have knowledge of key morphological features from many different species as opposed to
251 knowledge of only one species, as is the case of human hair examination, or a target species. For
252 MIAH, there needs to be awareness of somatic, inter- and intra-species morphological variations,
253 as stated by Lobert et al (21) ‘We emphasise the need for practitioners to gain considerable
254 personal experience of the technique, the diagnostic characteristics used to identify hair of
255 different species and intra-specific, in order to maximize the reliability of identification results’ .

256 *5.2 Forensic Human and Animal Hair Competencies*

257 A significant pitfall in relation to morphological animal hair identification is the assumption that a
258 practitioner competent in morphological human hair comparison is equally, and automatically,
259 competent in MIAH. However, both examinations have different goals and as such necessitate
260 different competencies in order to accurately conduct each type of analysis. Ogden (22) expresses
261 these sentiments thus: “. . . it is generally easier to teach a wildlife geneticist to do forensic (human
262 based DNA) casework than it is to convert a human forensic DNA specialist into a wildlife DNA
263 forensic scientist. A human (*sic*) forensic scientist attempting to learn the range of scientific
264 techniques and underlying biological assumptions involved in different wildlife identification
265 enquiries is faced with a very large, diverse body of knowledge to attain”.

266 Morphological identification of animal hairs is an exercise in classification that relies on the
267 recognition and interpretation of defined, genetically determined features present in all hairs from
268 animals belonging to a particular taxon. In contrast, human hair examinations rely on the
269 comparison of subjective, albeit genetic, characteristics (e.g. color, pigment type, and distribution)
270 and acquired characteristics (e.g. damage, artifacts, chemical treatments) in order to exclude, or not
271 exclude, an individual(s) as the possible source of the questioned hair. Therefore, forensic
272 practitioners solely trained and experienced in human hair comparisons do not automatically

273 achieve competency in morphological identification of animal hairs; the same logic applies to
274 those solely trained in MIAH, who would not be competent in human hair comparison.

275 *5.3 Atlases and Literature*

276 Whilst standard reference works (7, 8, 23, 24) serve as excellent examples to illustrate
277 morphological features useful for MIAH, it is crucial that the practitioner, experienced or
278 otherwise, is aware that these are not definitive or exhaustive works, either in regards to the range
279 of animals covered or in regards to all of the morphological features present in each hair type. As
280 Brunner and Coman (7) state in the preface to their animal hair atlas, “It is important to realize that
281 the photographs...represent only some of the multitude of structures observed in the hair of any
282 one species”.

283 Atlases are of considerable use in training hair examiners as they illustrate the diversity of
284 morphological characteristics present in animal hairs. However, as a sole basis for identification,
285 atlases are of limited utility as they offer ‘snapshot’ images of only one part of the hair;
286 furthermore, it is not uncommon to find that morphological features of hairs, from the same
287 species, differ in different atlases. Therefore, the use of these pictorial references should not be
288 used as substitutes for knowledge and information derived from the examination of vouchered
289 hairs, from a well-stocked reference collection. As Wildman (24) observed ‘. . . although books
290 and photographs are useful as guides, there is not reliable short-cut method for identifying animal
291 hair fibres by simply ‘matching up’ the microscopical appearance of an unknown fibre with a
292 photomicrograph’.

293 In relation to keys or other classification schemes that attempt to assist in the identification
294 process, Kirk noted: “Such schemes have a certain value when used with the reservations imposed
295 by experience and study, but their value even in this sense is limited. Experience in examining hair
296 and study of its characteristics will supply far more information than can be obtained by study of

297 any stereotyped classification scheme”(25). Although this was in relation to classification of
298 human hair types, this tenet is equally, if not more, applicable to MIAH for reasons outlined above.

299 5.4 Taxonomy and Binomial Nomenclature

300 Binomial nomenclature is universally understood. It not only crosses linguistic and cultural
301 boundaries, but it also ensures that there is no doubt as to the identity of the animal in question. In
302 a wildlife forensic context, an indictment is predicated on determination of the taxon represented
303 by the evidence and its legal listing as endangered or threatened.

304

305 The pitfall of referring to the animal in question solely by its common, or vernacular, name is
306 likely to result in misunderstandings or confusion in relation to the real identity of the animal being
307 discussed. Reference hair collections, or questioned hairs, identified with vernacular names are
308 likely to result in mis-identifications. For example, a sample labeled as dog may be hairs from
309 domestic dog (*Canis familiaris*) or raccoon dog (*Nyctereutes procyanoides*), which is a wild
310 species used in the fur industry. Fur apparel labeled as ‘dog’ may be mistaken as originating from
311 a domestic dog instead of a farmed raccoon dog, which may lead to accusations that furriers are
312 using domestic dogs in fur coats. In presenting testimony, we recommend the use of the common
313 name and binomial scientific name when the animal in question is first mentioned and thereafter
314 refer to the animal or taxon in question by its common name (a good example of the confusion that
315 can arise is exemplified by the work of Peabody et al (6) where *Felis catus* (domestic cat) was
316 confused with *Felis ocreata catus* (African wild cat)). Unfamiliarity with taxonomy and/or
317 binomial nomenclature of animals cannot justify the sole use of common or vernacular names; in a
318 forensic context the onus of unambiguously identifying the animal of origin of the questioned
319 hair(s) solely relies on the scientist presenting the evidence, not the jury, legal counsel or the
320 judiciary. In the provision of investigative leads, we would advocate the use of common names as

321 law enforcement personnel are likely to be non-specialists in relation to animal taxonomy, except
322 if there is a risk of misleading the investigators.

323 **6.Future Directions in MIAH**

324 *6.1 Promoting Best Practice*

325 A significant recent direction in MIAH, and other forensic wildlife disciplines, is in the formation
326 of the Scientific Working Group for Wildlife Forensics (SWGWILD). Founded in 2011 with
327 affiliation to the Society for Wildlife Forensic Science (SWFS)², SWGWILD brings together
328 world wildlife forensic experts to promulgate best practice across diverse species and evidentiary
329 material unique to this field through the provision of standards, education, and certification starting
330 with the disciplines of DNA and Morphology. The production of these guidelines and
331 recommendations for wildlife forensic practices is the first of its kind. As such, it is a significant
332 milestone in formalizing practices and standards for this discipline to ensure practitioners and
333 laboratories are appropriately qualified, accredited and competent to be regarded as experts in the
334 MIAH.

335 *6.2 DNA analyses and Microscopy*

336 Over the years the molecular analysis of animal DNA has steadily increased in the investigation of
337 poaching and trafficking in CITES listed mammals (26), animal cruelty cases and crimes against
338 the person in which animal hairs are submitted for examination (5). However, whilst these
339 analyses are routine in specialized forensic wildlife laboratories, this is not the case for many
340 forensic laboratories, which usually deal with crimes against the person. In cases in which animal
341 hairs are critical to investigations, species identification is commonly outsourced to specialist
342 laboratories. However, the costs are prohibitive for regular or routine use of these services.
343 Therefore, it makes good economic and efficiency sense to subject unknown animal hair
344 specimens to morphological analysis first in order to establish whether molecular techniques are

²<http://www.wildlifeforensicscience.org/swgwild/>

345 even required. Based on a global benchmarking process for forensic laboratories, FORESIGHT
346 (27) the average cost per case for a human DNA analysis is \$2,255 in 2012; if one or more items
347 can be excluded from analysis by a simple microscopical examination, the cost savings to the
348 laboratory can be significant. For example, it can be quickly decided whether the hair in question
349 is human, animal, plant, or textile fiber in origin. If it is assumed that DNA analysis of animal hairs
350 involves a similar cost then MIAH as the first step also makes economic sense for the same
351 reasons. This is likely to remain the case until such time as NGS is routine, simple, validated for
352 forensic purposes and more cost effective.

353

354 Research has shown the value of combining DNA analyses with the morphological examination of
355 human hairs (28, 29) and there is no reason to doubt that the two techniques will be also be
356 complementary in regards to animal hair identification as illustrated in the work conducted by
357 Shajpal et al (30) in relation to wildlife forensic cases. Whilst DNA sequencing can identify the
358 origin of an unknown animal hair and in time might even allow individualization within a species,
359 MIAH in addition to providing a highly reliable screen can provide additional value in relation to
360 mode of removal, effects of taphonomy, and identification of artifacts and treatments. For
361 example, in a hypothetical case, a large clump of 'big cat' hairs is found in the back of a suspected
362 poacher's vehicle but further microscopical examination shows the presence of post mortem
363 banding. This means that the hairs could only have originated from a decomposing body, which
364 opens up the possibility that the suspect may have merely picked up a dead body rather than
365 poached it.

366 **7. Conclusion**

367 Morphological identification of animal hairs is a robust and valid forensic technique; however, the
368 integrity of the results is wholly dependent on the availability of type/or vouchered reference
369 specimens and on the proven ability of the practitioner to accurately identify the animal of origin

370 of unknown animal hair based on morphological characteristics and to present appropriate
371 testimony.

372 Budowle et al (31) in their recommendations for animal DNA forensic and identity testing state “It
373 is important to operate under a set of minimum guidelines that assures that all service providers
374 have a template to follow for quality practices that can withstand legal scrutiny”. In this vein, from
375 our experience in the field of MIAH (which amounts to over 60 years total just for two authors),
376 we propose the following recommendations for legal practitioners, investigators, journal editors,
377 and forensic scientists to consider when producing or reviewing MIAH statements, publications or
378 reports.

- 379 • Microscopy. Scale patterns, medullae configurations, and root shapes (if present) must be
380 recorded and appraised using representative samples of each hair type present in the
381 sample. Scale patterns and medullae configurations should be determined along the length
382 of the hair shafts.
- 383 • Images. Images used to record MIAH must contain scale bars that are clearly visible, the
384 exception being scale cast patterns where it is inappropriate to include scale (since the
385 entire diameter of the shaft may not be in contact with the medium). Image legends must
386 include information on hair type, where on the hair the image was taken, and the somatic
387 origin of the hair (if known). All images should clearly and unambiguously demonstrate the
388 feature of interest.
- 389 • Descriptors. Nomenclature describing medullae and scale pattern configurations should
390 include the reference from which the descriptors are taken.
- 391 • Comparative analyses. Confirmation of identification must result from a comparative
392 analysis between the characteristics shown by the questioned hair and relevant hairs taken
393 from a vouchered specimen and the points of comparison recorded.

- 394 • Taxonomic identification. Common names must be accompanied by binomial
395 nomenclature i.e. scientific (Latin) names (at least at first mention)

396

397

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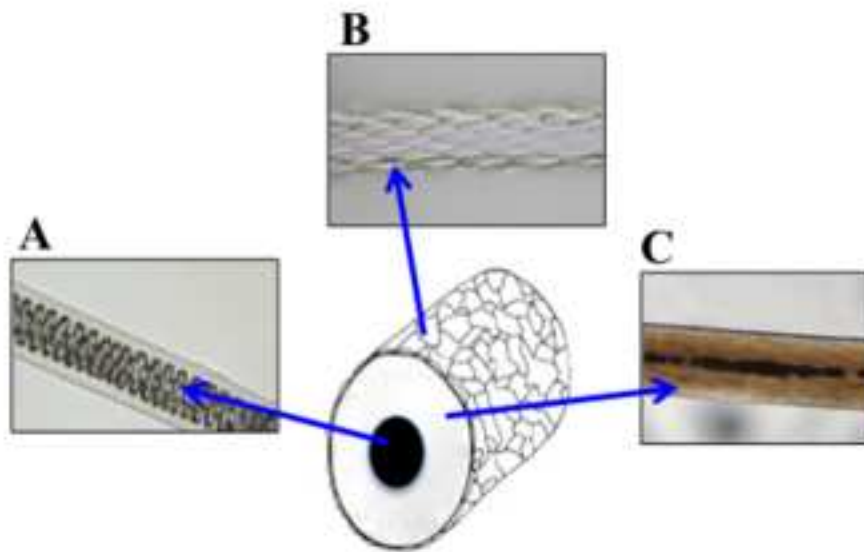


Figure 1. Generic diagram of a mammalian hair shaft (Centre) which consists of three major components the central core or medulla (A), cuticle (B) and cortex with pigment granules (C) (For illustrative purposes only)

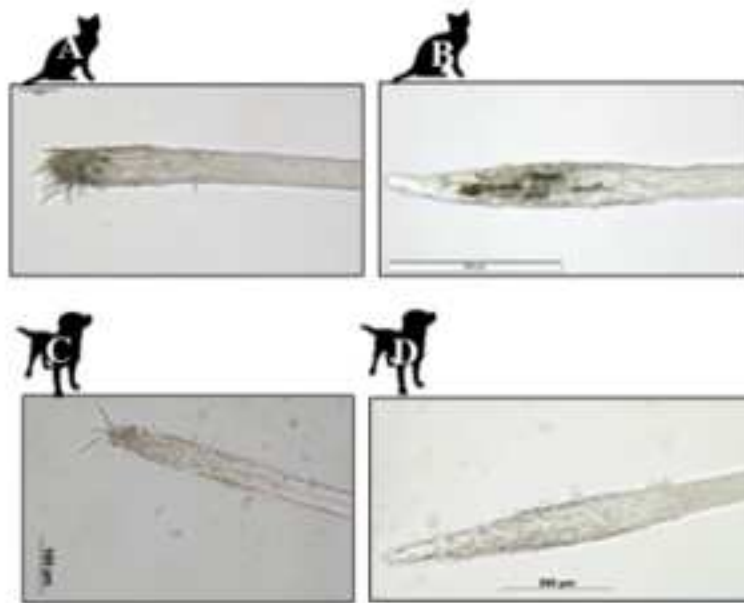


Figure 2. (A) Cat (*Felis catus*) guard hair with fibrillar root (bar 50µm);(B) overhair with spade shape root (bar 200µm). (C) Dog (*Canis familiaris*) finer guard hair with fibrillar root (bar 100µm); (D) coarse guard hair with spade shape root (bar 200µm)

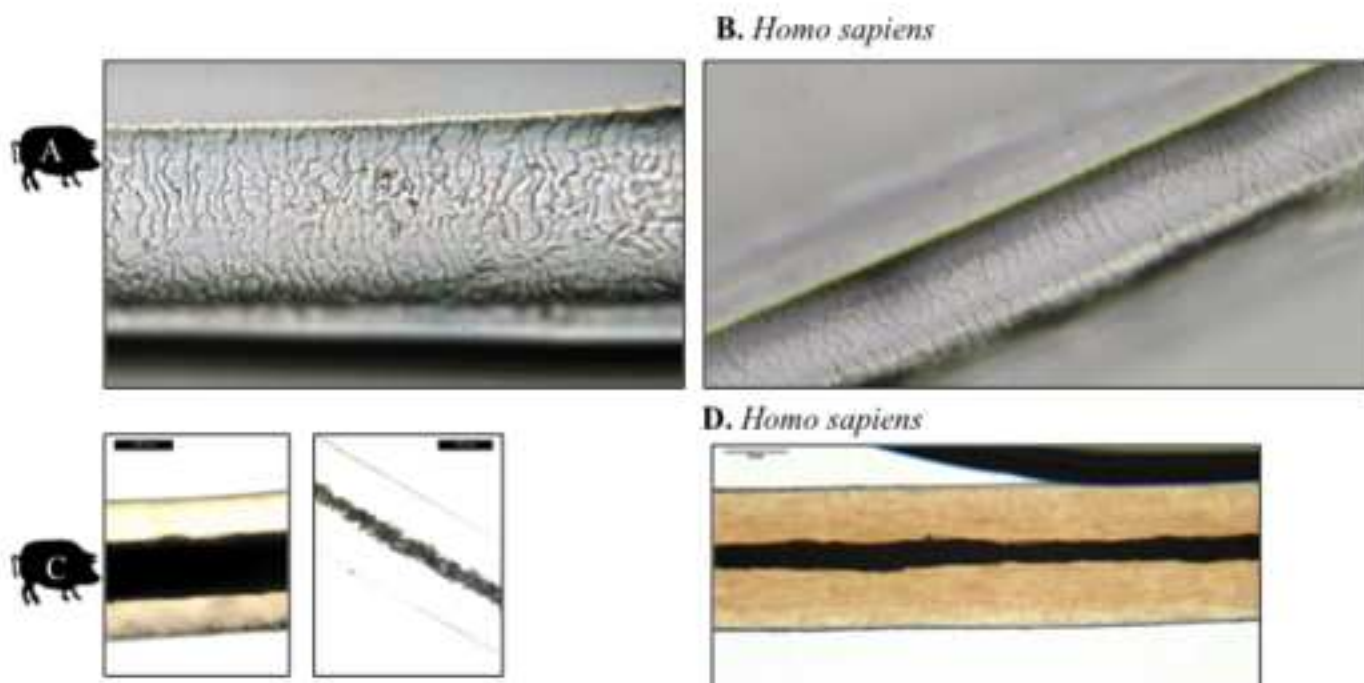


Figure 3. Images demonstrating that Pig (*Sus scrofa*) may be easily distinguished from human scalp hairs on at least two morphological characteristics. (A) (Pig) guard hair scale pattern showing close rippled margins of cuticle (guard hair along shaft length), compared with (B) human scalp hair which shows wider separation of scales.

(C) Medullae exhibited by pig body guard hairs (mid shaft areas) compared with (D) finer, amorphous medulla in human scalp hair (along shaft length)
 (scale bars: C) 100 μm ; D) 50 μm)

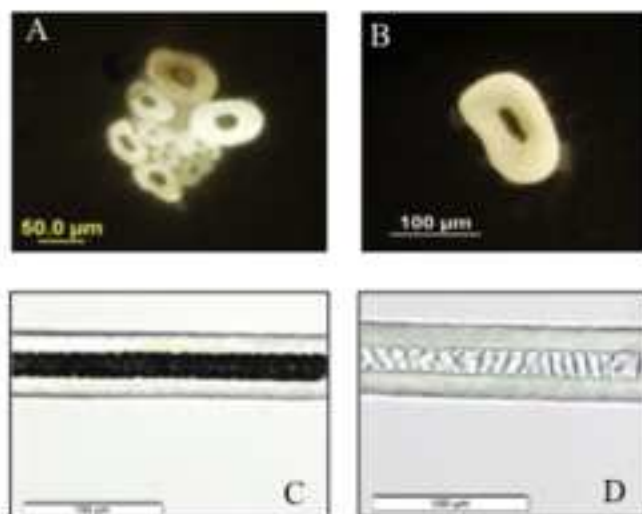


Figure 4. Transverse cross-sections of (A) polar bear (*Ursus maritimus*) dorsal overhairs and guard hairs (distal shafts) and (B) human beard hair, each showing a dark, central air filled medulla in unpigmented cortex. Polar bear guard hairs showing (C) air filled medulla and (D) translucent or 'cleared' medulla filled with mounting medium.

(Scale bars in C and D = 100 μm)

Fig. 1. Generic diagram of a mammalian hair shaft (Centre) which consists of three major components the central core or medulla (A), cuticle (B) and cortex with pigment granules (C)
(No scale bar, illustrative purposes only)

Fig. 2. Images of root morphologies that may occur on cats (*Felis catus*) and dog (*Canis familiaris*) hairs. Top panel cat guard hair with fibrillar root (bar 50µm), (B) overhair with spade shape root (bar 200µm). Lower panel: dog guard hair with fibrillar root (bar 100µm), (D) coarse guard hair with spade shape root (bar 200µm)

Fig. 3. Images demonstrating Pig (*Sus scrofa*) hairs may be readily distinguished from human scalp hairs, based on at least two morphological characteristics. *Top Panel* shows a close ripple scale pattern, with close margins on a pig guard hair (far left) and medullae exhibited by pig body guard hairs compared with human scalp hair which shows wider, smoother and regular wave cuticle scales and an amorphous central medulla.
(Scale bars: (C) 100 µm; (D) 50 µm)

Fig 4. Transverse cross-sections of (A) polar bear (*Ursus maritimus*) dorsal overhairs and guard hairs (distal shafts) and (B) human beard hair, each showing a dark, central air filled medulla in unpigmented cortex.
Polar bear guard hairs showing (C) air filled medulla and (D) translucent or 'cleared' medulla filled with mounting medium.
(Scale bars (C) and (D) = 100µm)