6 Forensic Examination of Animal Hair

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6.1 Introduction

The use of hair as evidence in criminal casework is well established, with hair being a common type of trace evidence retrieved from crime scenes (Petraco, 1987; Robertson, 1999). Hairs are readily lost from individuals, whether human or animal, and these hairs may be transferred during a crime, helping to link suspects to scenes, suspects to victims, objects to scenes or animals to individuals (to name but a few possible permutations). Edmond Locard's Exchange Principle (Locard, 1930), 'every contact leaves a trace', explains the mechanisms for trace evidence transfer at crime scenes. It is a fundamental principle that whenever objects, people or animals come in contact with each other, an exchange in material will occur. This includes hairs, fibres, glass, paint and any other particulate evidence. In the past, animal hair was disregarded as forensic evidence and not frequently analysed in forensic laboratories, but now animal hair is commonplace in forensic hair analysis (Petraco, 1987), partly due to development in identification schemes and research outlined in this chapter.

This chapter aims to provide to veterinarians, personnel who work in animal welfare (e.g. RSPCA officers), forensic scientists, police officers and anybody who may be tasked to analyse animal hair for criminal casework, an overview of forensic hair analysis. The focus of this chapter is to provide an insight into how animal hair evidence should be reliably recovered, documented, analysed and interpreted for criminal cases.

Human hair analysis will not be detailed in this chapter, but interpretation methods used when analysing human hair that are also applicable for animal hair will be introduced. Similarly, textile fibres evidence will not be focused upon, but as animal hair may be defined as a type of 'fibre', and are used abundantly in textiles such as clothing (Wildman, 1961), many of the underlying principles of recovery, documentation and interpretation are comparable and will therefore be described where appropriate.

6.2 Hair as Evidence

Hair can be defined as 'any of the fine thread-like strands growing from the skin of humans, mammals, and some other animals' (Oxford Dictionaries, 2014). Composed of the protein keratin, hairs are generally stable in nature, hence forensic scientists are able to use this type of evidence more readily in environments which have degraded other biological matter (Taupin, 2004). Hair evidence has been used in all types of criminal cases, including, but not limited to: murder, sexual assault, burglaries, abuse cases, arson and terrorist incidents (Robertson, 1999). This breadth of use is partially due to the ease of transfer of hairs between individuals, individuals and crime scenes and individuals and objects. Hairs transferred to highly important objects from a crime, e.g. a balaclava identified as being used in an armed robbery, enables the wearer to be identified and linked to the scene.

Hairs used in the analysis of a criminal investigation are defined as either questioned (aka target) or control samples. Target hairs are the extraneous hairs that have been transferred during contact and are the evidential hairs that will provide information about the case.

Hair evidence can provide a large range of different information beyond associations between suspects, victims, places and objects depending on the type and quantity of hair available. Hair evidence can provide intelligence information in the form of suspect descriptions, i.e. hair colour and type, as well as information regarding how the person treats their hair (for example, the use of styling products and dyes) and any diseases present in the hair. Examination of the hair can identify whether it is human or animal and the body area from which it has been shed. In the case of human hair, the ethnic origin of the individual the hair has been shed from may also be determined. If nuclear material is present on the root, then the potential for DNA profiling can allow for a more conclusive identification of the individual, beyond just microscopical analysis.

Hair evidence is a transient evidence and due to this the evidence will transfer and persist depending on certain factors (discussed in Section 6.8.2 below). By understanding transfer and persistence, timeframes of when certain contact occurred can help to reconstruct a crime scene and understand whether the evidence has been transferred at the time of the crime, thus making it evidentially useful. Hair evidence can also provide information about any drug use of an individual. Any damage to the hair can also provide the investigator with information about the crime and potential suspect(s); this includes heat, decomposition and fungal damage.

Hair evidence, like other evidence, has limitations. The lack of acknowledgement of these limitations in the past has led to miscarriages of justice and led to investigators overstating the value of the evidence (Taupin, 2004). The main limitations include the subjectivity involved in the microscopical analysis of hairs and the intra-variation in hair characteristics seen in individuals; this will be discussed later in the chapter. Knowledge of these limitations does not undermine hair evidence, but enables investigators to correctly interpret it.

6.3 The Use of Animal Hair in Criminal Casework

Hair evidence from animals has been used successfully in the solving of many human crimes; for example, when domestic dog hair has been transferred from the dog owner's clothes to a victim of a crime during an assault. The information that can be obtained from an animal hair is the same as in human hair, although some information is not applicable, such as ethnic origin. Animal hair analysis in criminal cases primarily focuses upon the species identification of the animal it originated from, although identification of a particular individual has been carried out. In terms of animal-related crimes, including wildlife crimes, hair analysis can be widely used: for example, illegal fighting involving dogs, cockerels or hogs (USA); intentional poisonings; poaching; carting of deer; ritualistic crimes; hit and runs; cruelty cases; badger baiting; import/export of endangered animals; and animal products and bush meat. In rare cases, animal hair may be utilized as the primary source of evidence, but more commonly it is used as corroborative evidence, analysed initially to obtain intelligence information or to justify further, more costly analysis (as a screening tool). Following are examples of the types of cases that utilize animal hairs as evidence (Case Studies 6.1, 6.2 and 6.3).

6.4 Recovery, Documentation, Packaging and Storage Methods for Animal Hair Evidence

It is important for anyone attempting to locate and retrieve animal hair evidence to be aware of the three Rs of evidence; Recognition, Recording and Recovery (Robertson and Roux,

Case Study 6.1.

A farmer had a prolonged problem with sheep worrying, culminating in one of her livestock being killed and mutilated. Veterinary examinations indicated that the wounds were probably caused by a dog, but this was not conclusive because of potential interference from scavengers. Hairs found in the wound of the sheep were retrieved and analysed and identified as being of canine origin, leading to further investigation, including DNA analysis, of the hairs. The owner of a local dog that was regularly walked in the area and whose dog had been seen chasing the sheep previously was questioned regarding the case, but refused to allow control samples to be taken from his dog for comparison. The information gathered in the analysis of the hairs was presented in court in order to obtain sufficient control samples and allowed a conclusion that the hairs from the wound and the dog could be associated, linking the dog to the sheep carcass.

Case Study 6.2.

Meat from a London market had been seized by the police as it was suspected to be illegally imported bush meat (described as gorilla meat). The meat appeared to have been treated (smoked and charred) but hair was still present on the skin (this is common with bush meat). Before testing of the meat, police wished to ascertain whether it was from an endangered animal or legal livestock such as bovine. Hairs taken from the skin were identified as being from sheep origin, thus eliminating the need for further analysis.

Case Study 6.3.

It was suspected that a racehorse was wrongly administered a drug over a lengthy time period; however, because the dose terminated one month earlier, removing the opportunity for blood and urine tests. Hair can provide information regarding type of drugs administered and drug use history, and, although hair is not as accurate in determining concentrations of drugs at a particular point in time (e.g. at the time of a crime or just before death), it can provide a profile of drug use over a long time period. Consequently, hairs were obtained from different clean locations on the racehorse, where there is low variability in growth rate and hairs had grown to sufficient length to span the suspected timeframe of the dosing. Segmental hair analysis was carried out. This is where the hair is cut into segments and analysed using a suitable technique, such as gas chromatography, to allow the time of administration to be identified by locating the position of the drug along the hair shaft. The results indicated the presence of clenbuterol hydrochloride in mane hairs extending back in time by 8 months.

2010). As evidential animal hairs are not necessarily easily seen when examining exhibits or animals, they may not be recognized without appropriate search techniques. Systematic searching of objects and animals for hair evidence should include looking for areas where hair transfer is most likely to have occurred during the incident rather than through innocent means, e.g. hairs found in a wound of an animal suspected of being involved in dog fighting is more evidentially valuable than if found just on the collar of the dog. To identify whether any hairs found are evidentially valuable, information such as whether the animal or object could have come in contact with any other animal should be sought, and if hairs have been taken from a scene, e.g. trailer or house, knowledge of animal access since the crime is required. Without correct recording of any animal hair evidence, then the evidential value may not be fully realized and, in the worst case, may not be admissible in court. Finally, without appropriate recovery methods, potential hair evidence will be left behind.

6.4.1 Recovery of questioned aka target animal hairs

Veterinarians and other individuals encountering live animals, carcasses or other objects potentially containing animal hair evidence need to know how to retrieve these transient samples reliably and efficiently before they are lost. The acronym GIFT (Get It First Time) is a principle that anyone attempting to retrieve evidence should abide by and an appropriate method must be chosen for the recovery of any questioned hairs (Robertson and Roux, 2010). The retrieval method used must allow all target hairs to be recovered, without loss or contamination. The recovery method chosen depends on a number of factors: surface type, surface area, presence of debris and whether the hairs are loose or embedded in the surface in which they are found. Table 6.1 outlines the seven methods that are accepted techniques for the retrieval of hairs.

Table 6.1. Methods for the retrieval of animal hairs.

Retrieval Method	Description of Use	Preferred Surfaces	Advantages	Disadvantages
Tape lifting	Sticky tape is gently placed on the surface, removing any surface hairs. Tape is then placed upon an acetate sheet to preserve the evidence and allow for searching (Choudhry, 1988).	Any dry porous or non-porous surface, especially useful for smaller surface areas, e.g. inside of pet carrier.	Able to capture multiple hairs at a time and also know from which part of an object the hairs have been retrieved from.	Hairs must be dissected from the tape to allow for further examination due to the need to encapsulate hair in a medium of similar refractive index (RI). This is time-consuming. A new tape, called Easylift, has been introduced that removes the need for dissection (Jackson and Gwinnett, 2013).
Tweezering	Use of clean tweezers to remove obvious hair evidence from surfaces.	All surfaces but usually only when hairs are found in prominent positions, could otherwise be easily lost and/or when the exact location of the hair is required to be known.	Good for when hairs are embedded within a substance or object, e.g. mud or a wound.	Time-consuming for large areas.
Vacuuming	Use of vacuum filters which attach to a vacuum cleaner and use suction to remove hairs.	Dry, large surface areas, e.g. pet bedding, large pet carriers.	Quick for retrieving large amounts of hair. Vacuum filters can be individually sealed.	More time-consuming than other methods when searching for target hairs, as there is usually a lot of 'background' information gathered in the form of debris and material from the surface itself.
Shaking	The object is shaken over a large collection funnel and any evidence collected in a Petri dish.	Fabric type objects, e.g. pet rugs.	Very quick method for retrieving loose evidence.	May miss evidence that is stuck in the weave of the fabric. Does not allow the exact location of the evidence to be identified.
Scraping	Use of a scalpel to remove very embedded hairs.	Any surface which has hairs embedded in it, e.g. painted surfaces.	Enables quick retrieval of hairs from situations that other methods would not be able to remove.	May damage hair during removal.
Combing	Use of a seeded comb (a comb in which cotton wool has been pressed into the base of the teeth or brush which removes and retains extraneous target hairs (McKenna and Sherwin, 1975).	Pelage of an animal.	Gently removes surface hairs without pulling out hairs from the animal.	Sampling a moulting animal may cause problems when trying to identify any target hairs present on the comb.
Filtering	Uncommon technique involving the use of different solvents to remove debris and extract hairs from contaminated samples.	Samples which are heavily contaminated with soil and other debris, e.g. buried samples.	Allows large numbers of hairs to be quickly extracted from soil.	Care is required to ensure that the solvents do not alter the hair evidence in any way.

6.4.2 Recovery of control aka known hair samples

Control samples are hairs that have been taken as reference hairs from any animal that could be involved with the crime or could have transferred hairs to any other animal, object or person linked to the crime. The taking of control samples from animals is usually undertaken after a police or court request. If possible, 20–30 hairs should be taken from different points on the animal, ensuring that all hair types have been retrieved and the samples represent the different lengths and colours present on the pelage. It has been suggested that a total of 400–500 hairs should be retrieved for comparison purposes (Suzanski, 1988). Control samples from animals should ideally be taken from a clean uncontaminated area and depending on the purpose of the analysis, for example, whether the hairs are for comparison only or for the analysis of the presence of drugs, additional considerations may be needed. Ideally hairs should be gently combed from the body, so as to allow the full hair to be collected (Wildman, 1961), but if this is not possible, hairs can be removed by cutting them close to the skin.

6.4.3 Packaging and storage

Prior to packaging, certain anti-tampering and anti-contamination procedures may be required. If a tape lift has been created, the edges of tape need to be sealed with additional tape. The evidence tape also must be scored with a scalpel so that it marks the acetate backing, but avoids damaging any evidence, protecting against fraudulent replacement. The type of evidence bag used for hair evidence depends on the police force and available equipment, but there are recognized procedures for the packaging and storing of such evidence. Loose hairs should be stored first in a labelled paper wrap, sometimes referred to as 'drug wraps' and then placed in a plastic evidence bag. Tape lifts and vacuum filters should be fully sealed and also placed in plastic evidence bags. If the hairs are wet with body fluids that are to be analysed for DNA, then the hairs should be packaged in a paper evidence bag and stored in a freezer.

6.4.4 Documentation of evidence

Normal documentation of evidence applies with animal hair, including the need to photograph evidence *in situ* and fully document when, where and who obtained it, along with a unique identifying number (Lenertz, 2001). Additional information is required for animal hair evidence when retrieving control hairs either for comparison to a questioned hair or for a reference collection. This may include the following:

- Known species and sub-species.
- Gender.
- Age (Wildman, 1961).
- Any known hair or skin diseases.
- Body area sampled (Wildman, 1961).
- Method of hair removal.

6.5 General Structure of Hair

Hairs consist of three regions; the root (proximal end), the shaft, and the tip – also known as the shield region in animal hairs (distal end).

In addition to this, hairs are composed of three main types of cell: cuticle, cortical and medulla. If a hair is envisaged as a pencil, the central graphite column of the pencil is the medulla, the wood surrounding the graphite is the cortex, and the paint on the outside is the cuticle. Figure 6.1 demonstrates the basic structure of an animal hair. Each area provides information about the hair and can contain distinguishing features. The cuticle is made up of overlapping scales that usually do not contain pigment (Partin, 2003). The cortex, consisting of spindle-shaped cells, makes up the main component of the hair, contains pigment granules and may also include small irregular-shaped air spaces called cortical fusi and larger solid oval structures called ovoid

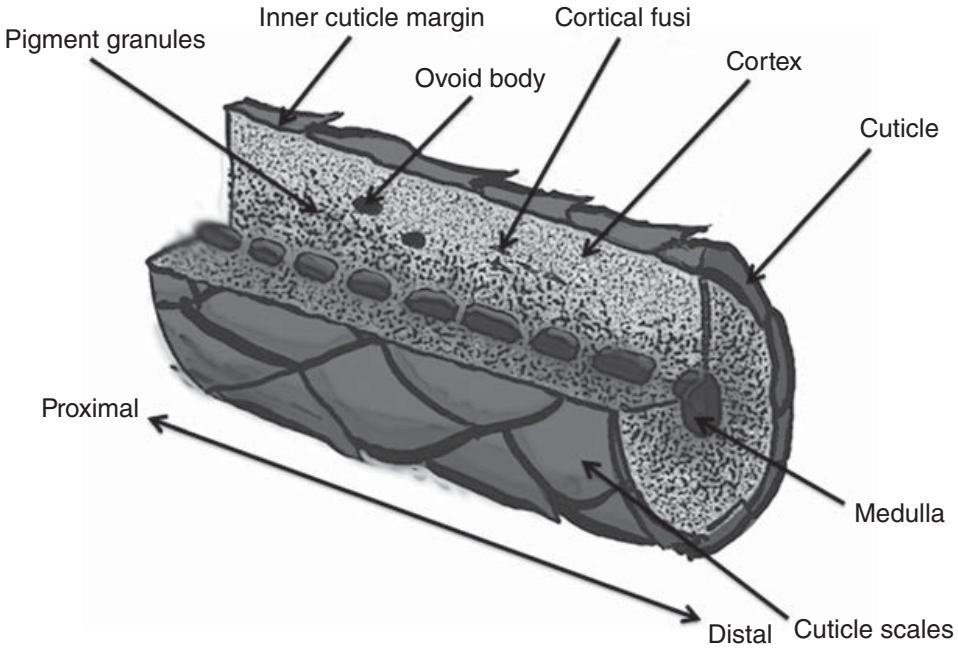

Fig. 6.1. Basic structure of an animal hair.

bodies. The medulla is a central core of shrunken cells with the spaces between the cells filled with air, and whose structure can vary dramatically in animal hair (Deedrick and Koch, 2004).

6.5.1 Types of hair

The complete covering of hair over a mammal is called the pelage. There are five main hair types that cover a mammal's body, serving particular functions such as heat preservation and sensory aids. Table 6.2 describes these five hairs and their general features.

6.6 Forensic Animal Hair Analysis

Forensic animal hair analysis focuses most commonly upon species identification, but may also include comparisons between target samples and controls, the latter being much more difficult. In addition to this, analytical techniques may be employed to ask specific questions about the hair, e.g. about the presence or absence of drugs. This chapter will concentrate on the microscopy of animal hair, as this is the most versatile and common technique used. A variety of questions beyond the species of the hair may be asked of the forensic hair analyst regarding a case, either by the police or in court. These may include the following:

- Do all species of animal have a combination of unique hair characteristics?
- How confident are you that the hair has originated from the particular animal in question?
- How and when did the hair evidence transfer to the scene/victim?
- Could the hair have been transferred innocently?

These questions need further work beyond the use of analytical techniques and need to take into account processes such as transfer and persistence and commonality of different characteristics, covered in Section 6.8 below.

6.6.1 Stages of hair analysis

Analysis of hair evidence usually starts with general observations about the number, condition and position of the hairs found. Analysis will also include some macroscopic observations, where the hairs

Table 6.2. Animal hair types.

Hair Type	Found?	General Characteristics	Evidential Value
Vibrissae (whiskers)	Nostrils and muzzle	Generally coarser than other hairs and are thickest at the root end.	Low Limited variations in this hair type between species mean limited value for identification and comparison (Teerink, 1991). There are some exceptions, such as tiger and leopard vibrissae, which exhibit differences in cross-sectional shape (Partin, 2003).
Over-hairs	Main pelage	Longer than other hairs present on the pelage. Generally coarse, straight with elongated tips.	Low, limited value for identification and comparison.
Under-hairs	Main pelage	Usually shorter and finer than the other hairs and show uniform thickness from the root to tip ends.	Medium Can aid species identification, but do not hold the same value as guard hairs.
Guard hairs	Main pelage	Commonly make the bulk of the pelage; coarser and longer than under-hairs but shorter than over-hairs.	High Have the greatest significance in species identification due to the interspecies variation present and the most useful when undertaking a comparison between a control and target hair (Suzanski, 1988).
Bristle	Found on the body of animals such as domestic and wild pigs and boar	Generally thick hairs with forked tips and with either absent, narrow or intruding medullas (Deedrick and Koch, 2004). Cross-sections are usually oval, circular or oblong.	Low

are placed upon a contrasting backing to allow general features such as colour, length, shaft profile and condition to be observed and can allow samples to be divided into smaller groups, e.g. under hairs and guard hairs. Shaft profile can sometimes be particularly useful when identifying species; for example, deer hairs have a distinctive crimped appearance (Deedrick and Koch, 2004).

The next stage of analysis is the use of high-powered microscopes in the form of a compound microscope (for the use of bright field microscopy) or a comparison microscope. Comparison microscopes are particularly popular, as they comprise two high-powered microscopes connected by a bridge which allows two samples, i.e. the control and the target sample, to be viewed at the same time under the same conditions.

Microscopy is debatably the most important stage of analysis and its advantages include the following: being a non-destructive technique; relative speed (important for timeliness of analysis, case throughput and if repeat measurements are needed); and its inexpensiveness, after the initial outlay (very few consumables). Sample preparation for fibres to be used for using brightfield microscopy is very simple, typically involving only placing the hair in a mounting medium between a glass slide and cover slip.

In some situations a polarized light microscope may be used; this allows the same observations as a compound microscope, but

also allows qualitative and quantitative measurements using plane polarized light and between crossed polars (where the sample is placed between two polaroid films). Although not regularly used by animal hair analysts, it does provide additional information about the hairs' optical properties, such as their interference colours seen under crossed polars. This property has been used in the analysis of exotic animal hairs (Partin, 2003).

Scanning Electron Microscopes (SEM) utilize high-energy electrons to scan the surface of the hair and may be used after compound microscopy to create high resolution, three-dimensional images at very high magnifications, allowing characteristics such as the scale pattern to be more clearly viewed, this can be seen in Bahuguna and Mukherjee's (2000) work on identifying Tibetan antelope hairs.

Finally, further analytical techniques may be utilized if additional information is required, such as dye analysis or drug analysis. Common techniques are High Performance Liquid Chromatography (HPLC) and Thin Layer Chromatography (TLC) for extracted dyes, and radioimmunoassays (RIA) and chromatography techniques, such as Gas Chromatography (GC), for the analysis of extracted drugs (Gratacos-Cubarsi *et al.*, 2006).

6.6.2 Microscopy preparation of animal hairs

Any target samples, or even control samples, which are covered in debris or body fluid must be cleaned prior to analysis. This can be completed by gently washing with distilled water and a mild detergent if necessary. Organic solvents such as isopropyl alcohol or acetone can be used to remove grease and other surface impurities (Ogle and Mitosinka, 1973).

If DNA analysis is possible, hairs should initially be mounted in distilled water so as to prevent any nuclear DNA being destroyed by a mounting medium.

6.6.2.1 Creating a whole mount

Mounting mediums such as Entellan® (Refractive Index (RI) = 1.49–1.51), DPX (RI = 1.52) or Meltmount® (RI = 1.539) are required for microscopical analysis. Refractive Index is the measure of the bending of light when passing from one medium to another. Generally, mounting mediums are thought to be best when they have a similar RI to the hair (keratin RI = 1.548) so as to allow a clear view of the internal characteristics of the hair (Petraco, 1987). Wildman (1961) describes the use of liquid paraffin (RI = 1.47) as a useful mountant, which is somewhat lower in RI than keratin, but allows both the internal features and surface characteristics to be viewed adequately. If the hair needs to be removed from the microscope slide and mountant, then this is possible by cracking the glass cover slip and applying a few drops of Tissue-Tek® Tissue-Clear®or xylene and then gently removing the loosened hair.

6.6.2.2 Scale casts and impressions of the animal hair surface

Prior to mounting on a microscope slide, a scale cast (or cuticle slide) can be produced to allow the outer scale profile to be determined. To do this, a thin layer of gelatine (10%–20%) (Teerink, 1991), polyvinyl acetate, Meltmount® (Petraco, 1987), or clear nail polish can be painted on to a microscope slide in a uniform thickness. The hair sample can then be placed gently into the substrate, leaving the end of the hair out of casting material for easier removal, and allowed to dry. If PVA is used, an additional slide can be placed on top of the hair and the slide gently heated to the melting point of the PVA and then allowed to cool before removal of the hair (Wildman, 1961). The hair can be rolled if a full impression is required as described by Wildman (1954), although this may damage the shaft and is not always appropriate, as the shield of the animal hair is normally slightly flattened in cross-section (Huffman and Wallace, 2012). When the substrate is fully dry, the hair can be carefully removed and the resultant cast can be viewed under a high-power light microscope.

6.6.2.3 Medulla slides

When the formation of medulla is difficult to visualize, a medulla slide may be produced,

which removes the air present in the medulla to allow for a detailed view of the structure. This is achieved by infiltrating the medulla with xylene or paraffin oil, which makes it transparent when viewed under a microscope (Teerink, 1991; Linacre, 2009). To do this, the hair is cut at various positions using a razor blade, such that the xylene can seep into the medulla. This process can take up to three hours. To make these permanent, the oil can be replaced with a medium such as Canada balsam (Teerink, 1991). The production of these slides is particularly useful for lightly pigmented hairs, but with some highly pigmented hairs, such as some primates and black bears, there must be additional treatment of the cortex to make it transparent. This can be achieved by submerging dry hairs in hydrogen peroxide and a few drops of ammonia solution until the desired lightness is achieved (Linacre, 2009).

6.6.3 Microscopical analysis of animal hairs

In microscopical analysis of hairs, a balance exists between observing the whole hair to identify species and/or any similarities and differences between control and target hairs. To achieve this, a systematic approach is required. Analysis evidence sheets can be used that provide a systematic method for noting down relevant characteristics, sketches and comments using standardized terminology; these analysis sheets simplify comparison and interpretation of the evidence. In an investigation, an analyst may be expected to analyse a few hairs, partial or complete hides, an object from a crime scene or a finished product such as a fur coat or hat (Linacre, 2009); therefore analysis methods must be adaptable but still recorded in a robust and reliable manner.

It is also beneficial to provide sketches and/or photomicrographs of the hairs. Sketches should include all three areas of the hair (root, shaft and tip) and be large, in ink, annotated, and signed and dated.

It is logical for an analyst to start at the root end, move through to the shaft area and then to the tip to identify any variation in characteristics and to view the whole hair. Each area can provide information specific to that region; for example, the root can provide information about the growth stage of the hair, the shaft can provide information about the pigment and medulla and the tip can provide information about damage and whether a fork or split is present.

For each of the cortex, medulla and cuticle regions, there are particular observations that are deemed useful for the analysis of hairs; these are listed in Table 6.3.

Figures 6.2 and 6.3 demonstrate examples of standard animal hair analysis forms and the categories used to describe the observations stated in Table 6.3. Further descriptions of the key observations can be found in Section 6.7, 'Species Identification from Animal Hair', below.

Table 6.3. Microscopical observations for the cortex, medulla and cuticle.

Hair Region	Characteristic
Cortex	Commonly noted: colour/hue, pigment density, pigment distribution, presence/absence of ovoid bodies. Additional observations: pigment granule shape, pigment granule size, texture of cortex, presence/absence of cortical fusi.
Medulla	Commonly noted: medulla distribution/type, medulla opacity, Medullary Index (MI) (Medulla diameter/shaft diameter). Additional observations: form of the medulla margins (straight, fringed, scalloped) (Teerink, 1991).
Cuticle	Commonly noted: cuticle thickness, scale pattern, scale position in relation to longitudinal direction of the hair, scale edge shape, distance between scale edges. Additional observations: distinctness of the inner cuticle margin.

ANIMAL HAIR EXAMINATION – SHEET 1						
Case reference:						
Page of						
Macroscopic characteristics						
Hair evidence number						
Length (cm)						
Shaft profile						
Colour						
Presence of banding						
General description:						
Examined by:						
Notes by: Day: Date: Time:						

Fig. 6.2. Example of a standard animal hair form: Part 1 (macroscopic observations and sketches).

In addition to these observations, the root growth stage may be noted: this can be categorized into anagen (active growth stage with the presence of nuclear material), catagen (transitional growth stage with limited nuclear material) or telogen (dormant stage where hairs are readily shed and no nuclear material present) (Robertson, 1999). The diameter of the shaft should be measured in micrometres using a calibrated eye-piece scale, and variation along the length of the hair should be noted.

Depending upon the particular crime, and when and where the hair was found, animal hair evidence may have been subject to external influences such as weathering

ANIMAL HAIR EXAMINATION – SHEET 2								
Case reference:								
Page of								
Microscopic characteristics								
Hair evidence number								
Pigment density	None							
	Light							
	Medium							
	Heavy							
Pigment distribution	Even							
	Central							
	Peripheral							
	One-sided							
Medulla distribution/ type	None							
	Broken (fragmented/interrupted)							
	Unbroken/continuous (lattice/aeriform lattice/simple/vacuolated)							
	Ladder (uniserial/multiserial)							
	Miscellaneous (globular/stellate/intruding)							
Scale edges shape	Smooth							
	Crenate							
	Rippled							
	Scalloped							
	Dentate							
Distance between scales	Close							
	Near							
	Distant							
Scale pattern	Mosaic (regular/irregular)							
	Wave (regular/irregular/single chevron/double chevron/streaked)							
	Petal (broad/elongate/diamond*)							
	Transitional							
Ovoid bodies (Y/N)								
Shaft diameter (μm)								
Root shape								
Tip shape								
Medullary Index (MI) = Medulla diameter/shaft diameter								
Other								
Examined by:								
Notes by:	Day:		Date:		Time:			

* note whether narrow or broad diamond

Fig. 6.3. Example of a standard animal hair form: Part 2 (microscopic observations).

(Chang, 2005), causing change in the morphological features, but nevertheless providing additional information about the case. In certain cruelty cases, animals may have been exposed to heat sources such as cigarette burns, irons or complete burning of the hair with accelerants. Hair samples found in bedding, discarded collars and at crime scenes can indicate the temperatures that hair has been exposed to.

When hairs are exposed to heat, changes in colour, swelling and bubbling of the hair may occur. Research conducted by Pangerl and Igowsky (2007) on human hairs indicated that variables such as temperature, exposure time, and how the heat is applied to the hair must be considered to fully interpret this type of damage. Research conducted by Ayres (1985) identified that colour changes occurred in hairs when exposed to a hot plate, but when exposed directly to flame, colour changes were absent; however, the presence of charring and bubbling was observed. Work conducted at Staffordshire University has shown that it is also possible to identify the presence of accelerants on even a few strands of hairs that have been in close range of an accelerated fire, using headspace gas chromatography.

Other environmental factors that cause damage to the hair, such as crushing, insect damage and fungal damage, can alter the appearance of the hair, but also potentially provides an evidentially useful characteristic. For example, hair from a decomposing body may exhibit a decomposition band, i.e. the section of hair lying below the skin surface has darkened in colour due to the decomposition process (Linch and Prahlow, 2001).

6.7 Species Identification from Animal Hair

It has been noted by Petraco (1987) and Moore (1988), that with use of their schemes of identification, even inexperienced examiners can accurately identify the species of an animal from its hair, albeit with use of other resources, such as reference materials (Moore, 1988). This comment should be taken with caution, as it is recognized that animal hair identification is one of the more difficult analyses attempted by forensic scientists (Wildman, 1961; Moore 1988). Possible explanations for this include: the variation that can exist within a species (Moore, 1988); the variation in terminology used in species identification keys; the subjective nature of the analysis (no single characteristic will allow identification of a species); and the fact that hairs from closely related species can show similar characteristics (Wildman, 1961).

For species and sub-species identification, there are five main characteristics: scale morphology; medulla type; medullary fraction (MF); colour banding; and root shape. The nomenclature for the different characteristics differs between ID keys and guides, but the following categories for each characteristic primarily combines the terminology and species examples used by Appleyard (1960), Wildman (1961), Petraco (1987), Moore (1988), Teerink (1991), Partin (2003), Deedrick and Koch (2004) and Linacre (2009). All examples are for guard hairs unless otherwise stated.

6.7.1 Scale morphology

Broadly the scale pattern of animal hairs can be classified into two main groups: coronal (where the scales go around the entire shaft, completely encircling it); and imbricate (where there are multiple scales encircling the shaft). Further classifications can be made of the scales on the cuticle by observing four main characteristics.

1. Scale position in relation to the longitudinal axis: this can be categorized as transversal (where the scales are at right angles to the longitudinal axis and appear to have a greater width than length – seen in Fig. 6.4f); longitudinal (where the scales are aligned with the length of the hair and are longer than they are wide – seen in Fig. 6.4b); or intermediate (where the width of the scales is the same as the length – seen in Fig. 6.4a).
2. Shape of the scale margin: this is the shape of the distal end of the scale, which can be smooth, crenate (shallow and relatively pointed indentations), rippled, frilled, scalloped or dentate (pointed, like teeth).
3. Distance between the external margins of the scales: this is usually categorized as close (as seen in Fig. 6.4g); near (as seen in Fig. 6.4a); or distant (as seen in Fig. 6.4b). Sometimes scale count is also completed, which counts the number of scales per unit of measure, e.g. 40µm (Rosen, 1974).

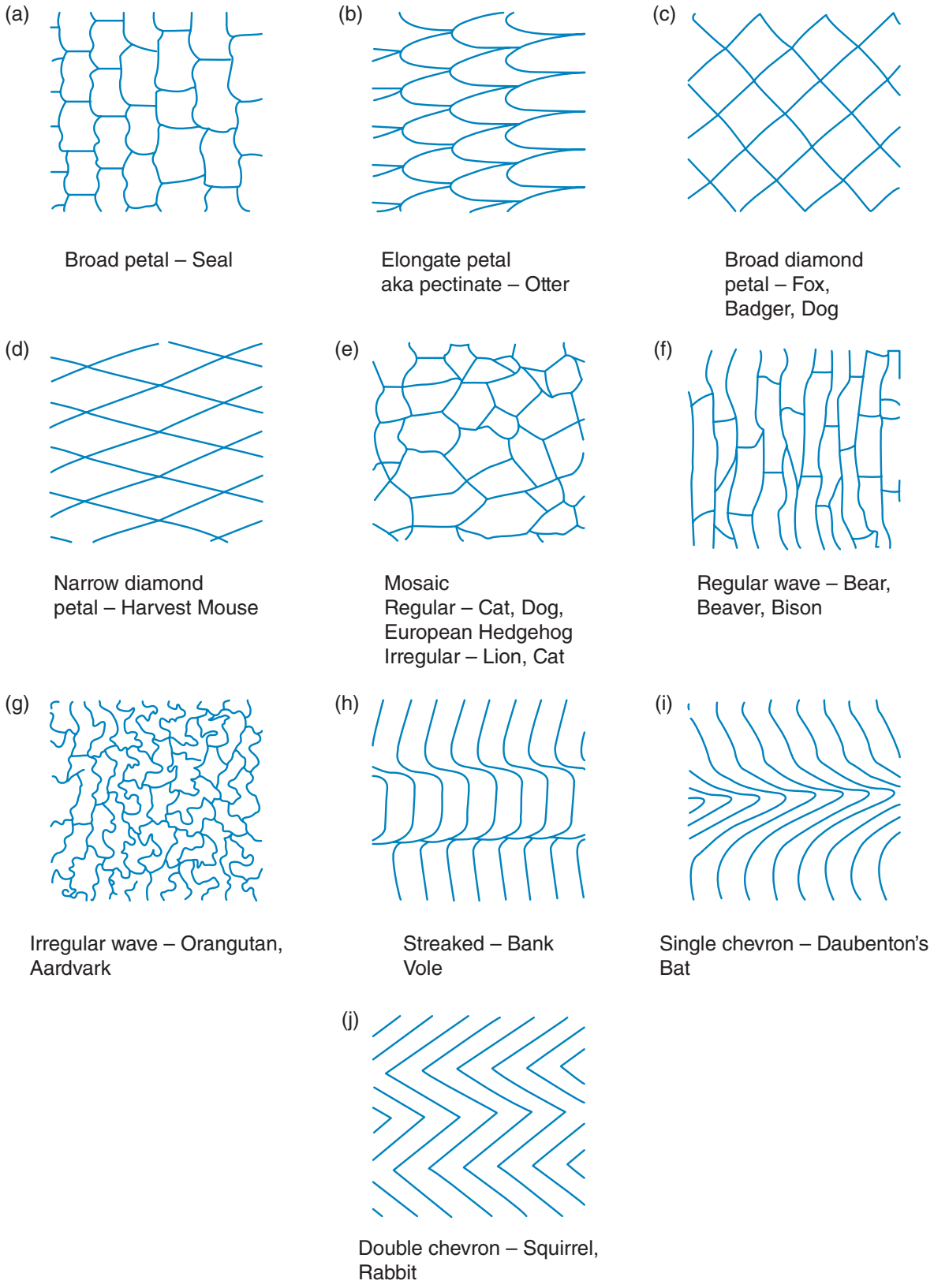

Fig. 6.4. Animal hair scale patterns.

4. Scale pattern: this describes the overall shape and regularity of the outer scales. Figure 6.4 demonstrates the most common patterns seen in animal hair, with some examples of animals that exhibit these. In addition to these, a pattern may also be transitional, which is the presence of more than one pattern along the length of the hair.

6.7.2 Medulla types

The medulla can vary dramatically between species and even subtle differences can be seen between sub-species. First, medullas can be categorized by their distribution as being unbroken, broken (e.g. interrupted and fragmented which is also seen in human hair), laddered, or miscellaneous; and then further categorized by their structure (and width, for certain types). Teerink (1991) also further categorized medulla by the form of the medulla margin, i.e. the silhouette of the medulla's edges, as straight, fringed or scalloped. Figure 6.5 demonstrates the most common medulla structures seen in animal hair, with some examples of animals that exhibit these.

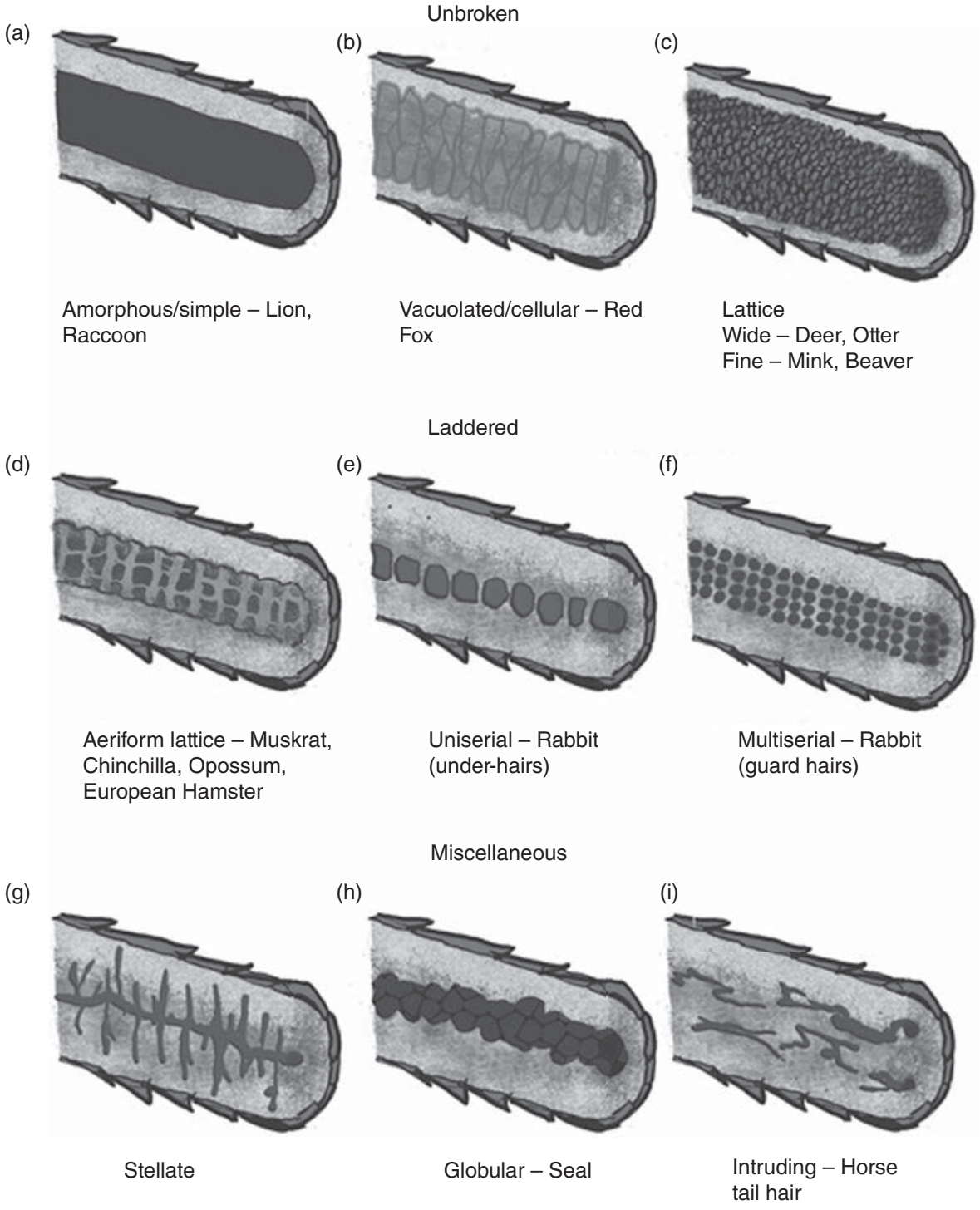

Fig. 6.5. Animal hair medulla distributions and structures.

6.7.3 Medullary fraction (MF) aka medullary index (MI)

The medullary fraction (MF) is the ratio between the width of the hair and width of the medulla. The width of both the shaft of the hair and the medulla are measured in micrometres and can be compared as a quantitative characteristic or used to aid identification; for example, Peabody *et al.* (1983) determined that the medullary fraction could be used to reliably distinguish between dogs and cats.

6.7.4 Colour banding

Pigment distribution in animal hair may not only differ across the width of the hair, but also quite dramatically along its length. The length, order, colour and number of bands can help identify different species. For example, badger hair can be differentiated from dog and fox hair primarily by its distinct white proximal end, black shaft and white tip (Moore, 1988).

6.7.5 Root shape

Further to identifying growth stage, animal hair root bulbs can have particular shapes that are useful in identifying species. Examples of this include deer (wine glass), horse (elongated), cow (elongated but with a medulla present in the root portion), dog (spade) and cat ('paint brush' with the inclusion of fibrils) (Moore, 1988; Linacre, 2009).

6.7.6 Species identification aids

Research into the variation of morphological characteristics in animal hair, comparisons of different species and sub-species, and the development of identification keys, reference collections and interpretation aids are abundant. Examples of specific ID schemes include the following: Stains (1958); Appleyard (1960); Moore (1988); and Petraco (1987). Petraco's (1987) scheme includes 25 genera and was designed to allow quick and effective identification of these genera using only one complete guard hair. Moore's (1988) scheme mainly focuses upon animal species commonly found in the UK, but also incorporates other species such as camel and llama. A comprehensive atlas of west-European hairs developed by Teerink (1991) provides illustrations and photographs of cross-sections, scale casts, medulla slides and mounted samples of guard and under-hairs from a vast range of animals. Smaller research projects analysing particular species or geographical area either for casework or other environmental or scientific purpose are also very useful to the hair analyst. Examples of these types of study include Williams' (1938) ID of mole and shrew hairs; Hilton and Kutscha's (1978) ID of coyote, dog, red fox and bobcat hairs in Maine; Vineis *et al.*'s (2008) ID of wild goat and domestic goat hair; and Mayer's (1952) examination of Californian mammals. In addition to these works, there are very useful online resources that present photomicrographs of different animal hairs, including Deedrick and Koch (2004).

These guides are very important for forensic analysts who may not have come across certain animal hair types in casework previously. Some of these keys state different characteristics for the same species type but this is to be expected, as different sub-species will have been sampled for the production of the keys and therefore the use of multiple keys, to identify any variation and differences in interpretation, is advised.

The breadth of animal hairs and their microscopical characteristics is huge and it is advisable for a forensic analyst to have reference samples of a large range of animals for comparison (Wildman, 1961). Samples may be obtained from casework, museums, zoos or commercially produced collections, such the Arbidar Animal Hair and Fur Collection.

6.8 Interpretation of Animal Hair in Casework

6.8.1 Conclusions from comparing control and target hairs

The interpretation of the characteristics observed between target hairs and control