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Hair Shaft Anatomy of Mammals: A Comprehensive Overview

Vinayasheela S*, Purushotham G

Department of Veterinary Anatomy, College of Veterinary Science, Hyderabad, Telangana

Research Article

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***For Correspondence:** Vinayasheela S, Department of Veterinary Anatomy, College of Veterinary Science, Hyderabad, Telangana;
E-mail: Vinayavet1012@gmail.com

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ABSTRACT

Hair is composed of root and shaft of which latter was an epidermal outgrowth consisting of outer cuticle, middle cortex and inner medulla. The cortex was non-cellular and the medulla was cellular made up of cornified cells. The features of guard hair vary from species to species which is an important tool in identification of species. Analysis of hair is an easy method which is used in forensic medicine, zooarchaeology, anthropology and ecology. Wild animals are being pouched and killed for their meat, skin, tusks etc. The cuticular pattern, medulla type and cortex pattern are species specific which are the main features that helps in differentiating the animal species. Animal hair examination at a criminal scene may provide valuable information in forensic investigations.

Keywords: Shaft; Medulla; Cuticle; Cortex; Scale pattern

INTRODUCTION

Identification of hair has been used in forensic medicine, taxonomy, palaeontology, zooarchaeology, anthropology and ecology [1]. Mammalian hair is the best source to solve biological problems like species identification and diet analysis of endangered large carnivores because it is very difficult to examine the intestinal contents of those animals [2]. Further, drugs, chemicals and biological substances accumulate in hair can be detected and measured. It is strongly resistant to decomposition and is stable under adverse conditions [3]. However, there is a need for preliminary biological studies which has to be necessarily carried out at basic level for comparative macro and micro anatomical features of hair. Undoubtedly DNA diagnostic studies provide ultimate evidence for hair during crime or forensic investigations [4]. Many a times features and traces of materials on hair unrelated to the issue of identity were ascertained rapidly by microscopic hair analysis. Hence, the comprehensive features of animal hair shaft were described in the present study [5].

MATERIALS AND METHODS

Tip of hair

The tip was the region most distal from the basal part of the hair and it had one proximal color demarcation [6]. Tip was devoid of medulla and tappers gradually. In humans, different types of tips like tapered, rounded, square cut, angular cut, frayed, split, crushed, broken and singed were noticed [7].

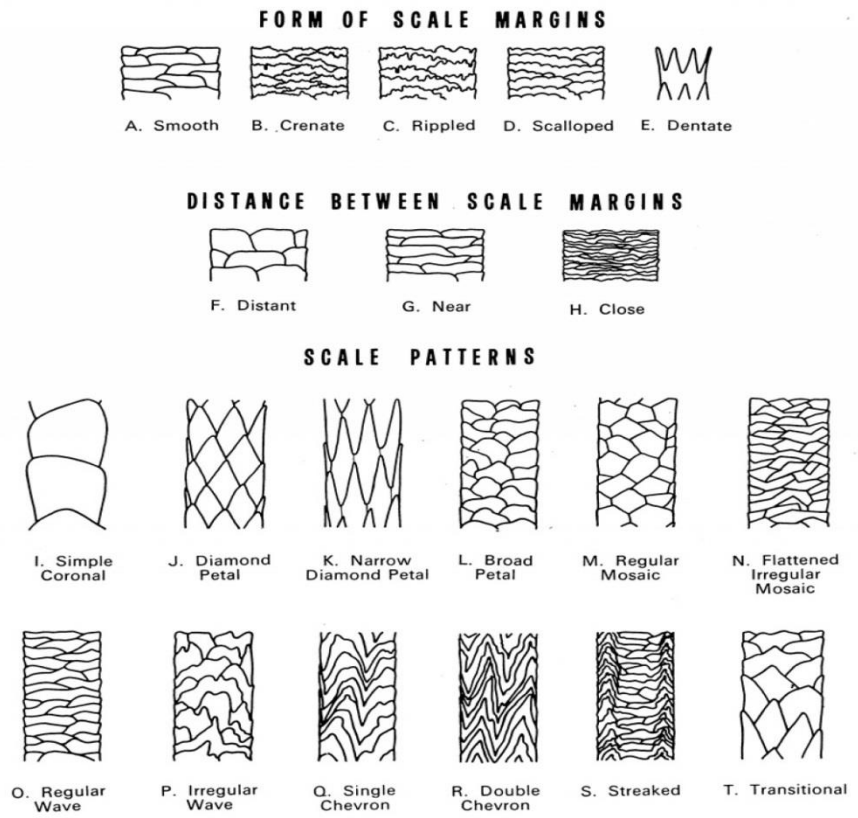
Color of the hair

Robertson described that color variation of hair within an individual and within a single hair which was due to differences in their exposure to the environment [8]. Radical color changes within the shaft of many animals at short distances was known as banding. Color was a variable feature which was affected by age, season and regions. The dorsal guard hair of five primate species varied between brown and black [9].

Cuticle

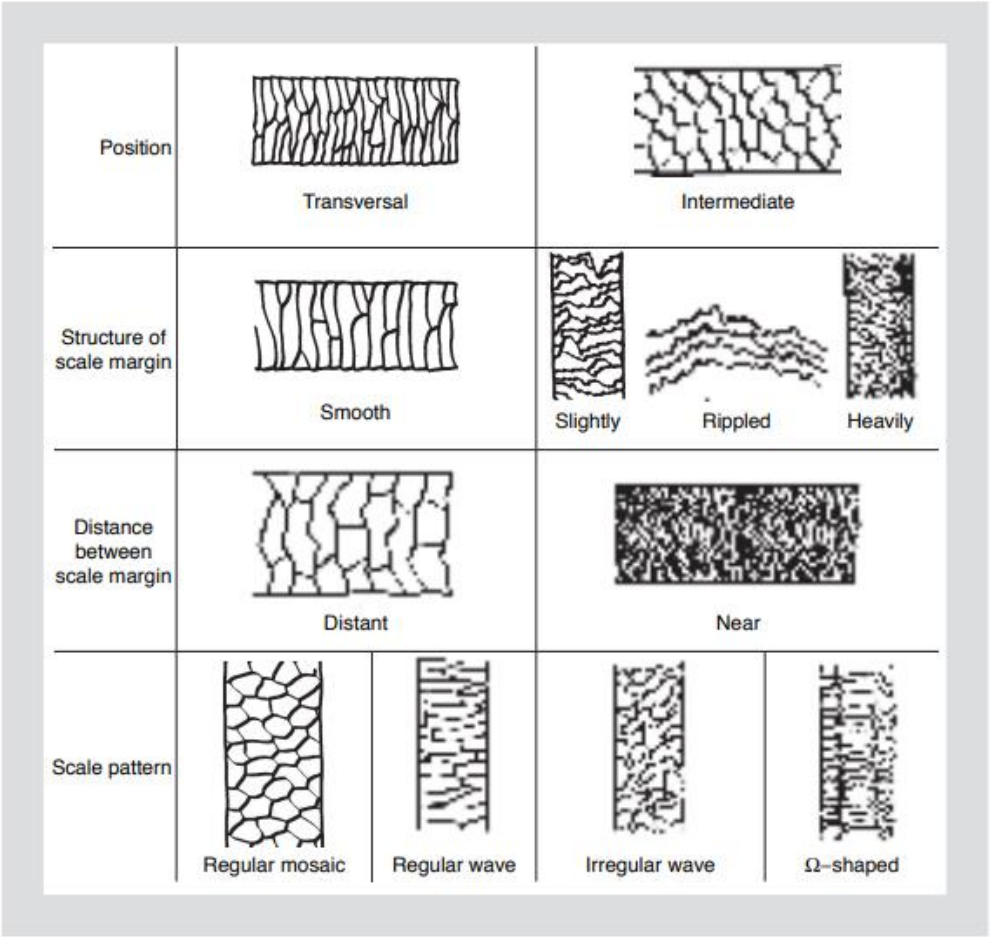
The cuticle was a translucent outer layer of hair shaft made up of overlapping pigment free keratinized scales. The distal edges of scales were free and pointed towards the tip and its color was either black or brown [10]. Study of scale pattern was the most important factor in the microscopic study of hair structure. In many animals, cuticle was regular with repeating pattern making it a distinguishing feature from human hair where the scale pattern was non-repeating imbricate type [11]. Scale pattern of animal hair was categorized into coronal, petal, chevron, mosaic and pectinate types. The basic structural patterns of cuticle in animal hair were coronal (crown like), spinous (petal) and imbricate (flattened) types. Coronal scale pattern in fine hair resembled a stack of paper cups [12]. Scales in spinous pattern were triangular and protruded from the hair shaft whereas in imbricate pattern they consisted of overlapping scales with narrow margins. Animal hair consisted of various structural combinations of scale patterns [13]. Cuticle pattern of domestic ruminants was denticulate (bovine), reticulate (ovine) and squamous (goats). The scales were classified as transversal and intermediate scales based on the position of scales in relation to longitudinal axis while they were smooth and rippled based on their structure of scale margins (Figure 1) [14].

Figure 1. Classification of scales and scale margins.



The scale pattern was regular mosaic, regular and irregular wave and 'Ω'-shaped. Based on the scale interval they were called near and distant scales (Figure 2).

Figure 2. Classification of scales of domestic and wild ungulates.



Number of scales per 100 µm were 5-10 in African lion and fruit bat, 10-15 in Orangutan and Aardvark, 8-12 in brown bear [15]. In domestic animals, the average number of scales across mid shaft region ranged between 2-4 in cattle and hybrid yak, 2-6 in domestic goat, 3-5 in marmot, 3-8 in domestic sheep, and in wild animals it ranged from 4-5 in pika, 5-7 in ibex, 5-8 in markhor and 13-16 in musk deer [16].

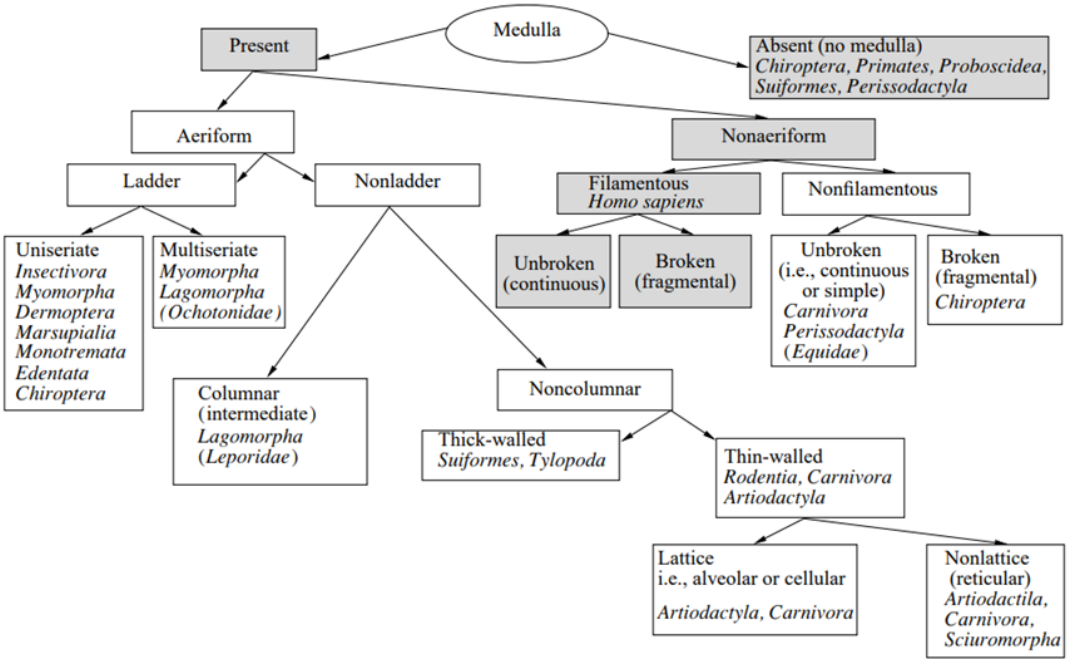
Cortex

Cortex was the main body of the hair comprising of keratinized, elongated and fusiform cells held together by matrix proteins [17]. Cortex in human hair was the middle layer of the hair shaft made up of spindle shaped cells which inter digitated with each other along the long axis of the shaft [18]. Cortex pattern was classified into smooth, serrated, cracked and looped. Cortex consisted of dense clumps of undispersed pigment called ovoid bodies.

Medulla

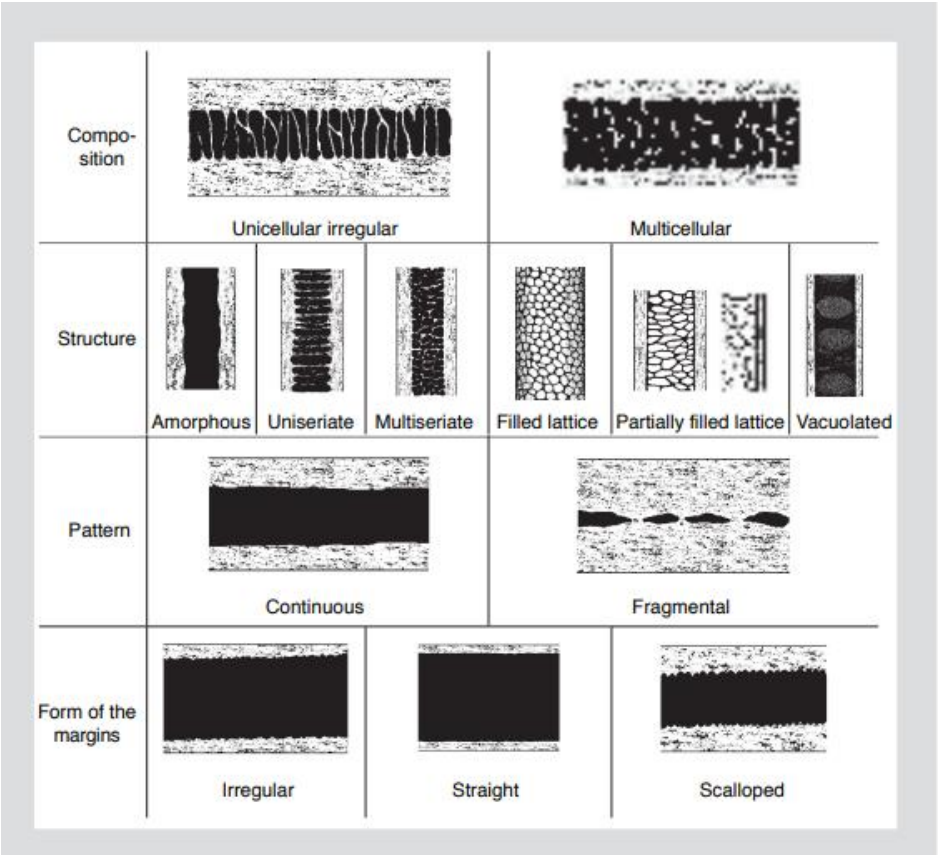
Guard hair consisted of central cellular marrow called medulla. Guard hair of some species were devoid of medulla [19]. Medulla of mammalian hair was classified as discontinuous, continuous and intermediate or fragmentary type which consisted of stacked and juxtaposed cells with air chambers (Figure 3) [20].

Figure 3. Classification of medulla of guard hair of mammals, shaded blocks indicate human medulla.



Based on appearance of air spaces, medulla was named as aeriform and non-aeriform of which, the was further divided based on arrangement of cells into ladder and non-ladder type. Non-aeriform type was classified into filamentous and non-filamentous which was continuous and fragmentary. The ladder type may be uniseriate and multiseriate. The non-ladder medulla was categorized into columnar and non-columnar medulla of which later comprised of thick or thin walls which may be cellular or reticular type (Figure 4).

Figure 4. Types of medullae of mammalian guard hair.



Air filled medulla appeared dark while fluid filled medulla was like bubbles when viewed under transmitted light microscope. Medulla of ungulates (Figure 4) also showed vacuolated cells Medullary margins were irregular, straight and scalloped in ungulate hair. Compound hair consisted of multiple medullae as reported by Yates et al., in tail clutch hair of elephant.

RESULTS AND DISCUSSION

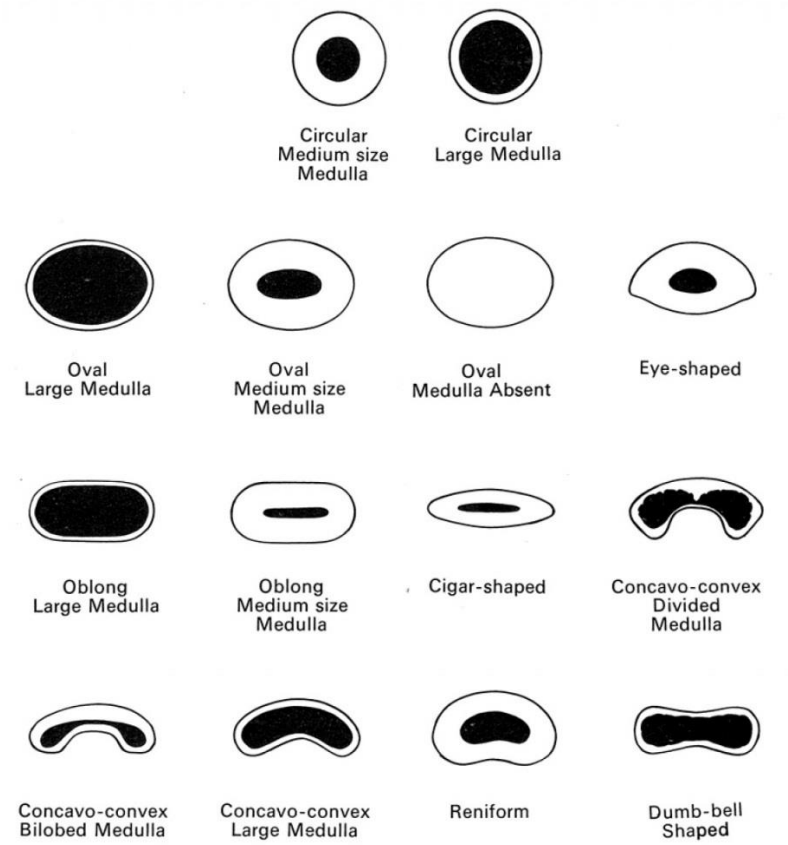
Pigment distribution

Pigment granules were located in the cortex and medulla which were dense and evenly distributed towards the cuticle of human hair, whereas it was distributed more centrally and denser towards the medulla in animals. The pigment distribution in hair was uniform, peripheral, one-sided, random or variable, central or medial and pigmented in cuticle.

Cross section

The cross-sectional shape (Figure 5) of a single hair shaft was variable throughout its length. Bourliere et al., classified cross sectional shape of hair into convex, concave and angular profiles. Convex profiles might be round or oval. Concave profiles could be one, two, three or four sided. Indentations by a deep and wide longitudinal groove on one side and a smaller shallow longitudinal groove on the opposite side resulting in a dumb-bell shaped profile as reported by Sahajpal et al., in Pashmina goat.

Figure 5. Showing the cross-sectional shapes of mammalian guard hair.



Micrometry

Micrometry of hair is a quantitative parameter used to differentiate between human and animal hairs. It is used to estimate the age of captured animals which suggested considerable intra specific variation in hair features. Diameter of mammalian hair varied from root to tip. The diameter was smaller towards root than in the middle part of the shaft while the shaft

tapered gradually to a point at the tip. The diameter of human hair from different regions ranged between 30 to 80 µm while those in animals was 25 to 160 µm. Oien classified hair shafts with diameter between 40 to 50 µm as very fine hair and those between 110 to 120 µm as coarse hair. Diameter of hair is an important parameter that played a significant role in the classification of racial groups. Mean medullary diameter of hair was 20 µm in rat and cat, 100 µm in cow, 5 to 20 µm in human hair. According to Anwar et al., medullary diameter of yak hair was 4 µm, 5 µm in pika, 6 µm in domestic sheep, cattle and marmot, 8 µm in domestic goat, hybrid cattle and yak, 1 µm in ibex, 13 µm in markhor and 28 µm in musk deer.

Medullary index

Medullary Index (MI) was the ratio of medullary diameter to the shaft diameter.

$$\text{Medullary Index (MI)} = \frac{Maximum\ diameter\ of\ medulla}{maximum\ diameter\ of\ shaft}$$

Medullary Index was one third or less in humans whereas it was more than one third in animals due to the greater width of medulla. Medullary Index was 0.76 - 0.82 µm in the hair of pashmina goat, 0.96-0.98 µm in Tibetan antelope, 0.35 µm in orangutan, 0.44 µm in African lion and 0.14 µm in brown bear.

CONCLUSION

It is concluded that, the anatomical feature of hair shaft varied from species to species which plays a key role in species identification and was important evidence in crime scenes and veterolegal cases. The hair shaft shape, medulla, medullary index and cuticle were species specific. The medullary index was the key feature that helps in differentiating human to animal hair. Hence, the detailed study of microanatomy hair shaft with further insight into molecular details will help in biomedical field.

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