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Structural Variation of Cuticular Scale Patterns Across Functional Regions of Mammalian Coats

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Abstract
This study was conducted to identify and characterize the distinct cuticular scale patterns present on the hair shafts of various domestic animals. The outer surface of mammalian hair is covered by microscopic, overlapping structures known as cuticle scales, which serve to protect the underlying cortex and medulla. Due to their structural resilience, hair shafts maintain their chemical and histological integrity over extended periods. For this investigation, shed hair samples were collected from six domestic species: dog (Canis lupus familiaris), cat (Felis catus), horse (Equus caballus), cow (Bos taurus), goat (Capra hircus), and buffalo (Bubalus bubalis). Reference control samples were gathered from livestock owners across the Umarkhed and Mahagaon regions of Maharashtra State during 2026.
Keywords *- Canis lupus familiaris, Felis catus, Equus caballus, Bos taurus, Capra hircus, Bubalus bubalis.*

Introduction

Hair represents a specialized integumentary outgrowth that fulfills essential physiological roles, including thermal regulation, structural streamlining, water repellency, and physical defense (Kulshrestha, 1992). The scientific discipline devoted to hair analysis—trichology—emerged during the mid-nineteenth century. Early systematic studies on mammalian hair morphology were pioneered by L.A. Hausman (1920, 1924, 1930), whose comparative anatomical illustrations formed an early cornerstone for taxonomic classification.

Because hair trace evidence is regularly recovered from crime scenes, its analysis is fundamental to forensic science, wildlife law enforcement, comparative taxonomy, clinical dermatology, and pathology (Sahajpal et al., 2009; Bahuguna et al., 2010). Microscopic examination focused on medullary configurations and cuticular scale architecture allows researchers to reliably differentiate taxa across multiple disciplines.

In ecological contexts, hair micromorphology provides non-invasive insights into predator-prey diets and habitat quality metrics through small-mammal community profiling. Additionally, these analytical techniques are widely applied in anti-poaching enforcement, aiding in the prosecution of illegal hunting and the authentication of commercial fur garments (Mathiak, 1938; Williams, 1938; Mayer, 1952; Adorjan & Kolenosky, 1969).

Material And Methods:-

Reference control samples were collected from livestock owners across the Umarkhed and Mahagaon regions of Maharashtra State during 2026. For this investigation, shed hair samples were obtained from six domestic mammalian species: dog (*Canis lupus familiaris(german shepherd*), cat (*Felis catus*), horse (*Equus caballus*), cow (*Bos taurus*), goat (*Capra hircus*), and water buffalo (*Bubalus bubalis*).

Cuticular scale impressions were prepared following the standard methodology outlined by Brunner and Coman (1974). A thin, uniform film of clear nail polish was applied across a microscopic glass slide using a glass rod. Hair strands were placed gently onto the wet film, leaving both ends protruding beyond the edge of the slide for easy retrieval. After air-drying for approximately 25 minutes, the hair shafts were carefully removed using forceps, leaving distinct cuticular surface impressions.

Physical properties, cuticular characters, and medullary configurations were examined under a binocular compound microscope at 40 × your 100 × magnification. Key microscopic

parameters—including hair pigmentation, texture, scale margin morphology, inter-scale distance, cuticular scale pattern, and medullary continuity—demonstrated distinct species-specific variations. These diagnostic features reinforce the utility of hair micromorphology in wildlife forensics and species identification.

Results And Discussions-

1) **Dog (*Canis lupus familiaris(german shepherd)*)** - The hair of the dog (*Canis lupus familiaris* – German Shepherd) exhibits a scale pattern that transitions primarily from coronal to imbricate, displaying irregular wavy-crenate profiles across the hair shaft. Microscopic examination reveals that the scale margins range from smooth to rippled, while the inter-scale distance varies from close to moderately spaced.
2) **Cat (*Felis catus*)** – The hair of the domestic cat (*Felis catus*) features an imbricate (overlapping) scale pattern characterized by irregular, tooth-like shapes. The scale margins are distinctly crenate with prominent toothed edges, and the inter-scale distance is characteristically close-spaced.
3) **Horse (*Equus caballus*)** – The hair shaft of the horse (*Equus caballus*) is characterized by transversely arranged, elongated imbricate scales that display a distinct, irregular wave pattern across its surface. Morphological analysis indicates that the scale margins are irregular crenate, separated by an intermediate inter-scale distance.
4) **Cow (*Bos taurus*) –**The hair shaft of the cow (*Bos taurus*) exhibits flattened, overlapping imbricate scales arranged in regular wave patterns, closely resembling shingles on a roof. Microscopic examination demonstrates that the scale margins are distinctly crenate, with an intermediate inter-scale distance separating individual cuticular units.
5) **Goat (*Capra hircus*) –**The hair shaft of the goat (*Capra hircus*) is characterized by an imbricate scale pattern prominently arranged in a distinctive herringbone configuration, forming a V-shaped, staggered pattern across the surface. Depending on the anatomical location (such as the neck, lumbar, or croup region), the individual scales range from slightly wavy to flattened, with occasional rippled or irregular variations. Furthermore, the scale margins are predominantly crenate, and the inter-scale distance ranges from intermediate to close.
6) **Buffalo (*Bubalus bubalis*)** The hair shaft of the water buffalo (*Bubalus bubalis*) is characterized by an imbricate scale pattern exhibiting irregular wave or rippled configurations rather than straight edges. Microscopic examination indicates that the scale margins range from rippled to crenate, while the inter-scale distance is closely to regularly spaced along the length of the shaft.

Table 1. Description of Scale pattern on different domestic animals hair

Species	Scale Pattern	Margin Morphology	Inter-Scale Distance	Distinctive Features
Dog	Coronal / Imbricate	Smooth to rippled	Variable / Close	Irregular wavy-crenate profile
Cat	Nesting	Crenate (tooth-like)	Close	Irregular, sharp-edged scales
Horse	Nesting	Irregular crenate	Intermediate	Elongated, transverse waves
Cow	Nesting	Regular crenate	Intermediate	Shingle-like regular wave pattern
Goat	Nesting	Crenate to rippled	Intermediate	Diagnostic herringbone (V-shaped) arrangement
Buffalo	Nesting	Rippled / Crenate	Close to regular	Wavy, non-straight scale borders

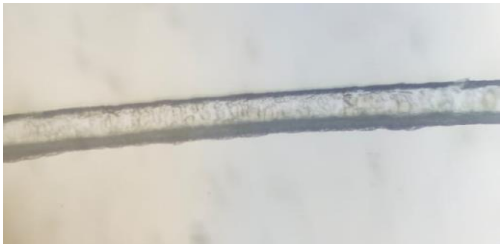
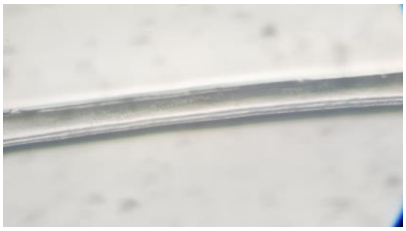
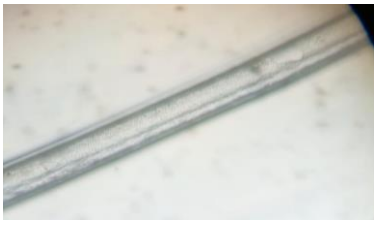
Species	Photos
Dog	
Cat	
Horse	
Cow	
Goat	
Buffalo	

Image : Microscopic images of different domestic animals hair by using compound microscope (40 X)

Discussion -

The microscopic analysis of cuticular scale patterns across the six domestic mammalian species examined in this study (*Canis lupus familiaris*, *Felis catus*, *Equus caballus*, *Bos taurus*, *Capra hircus*, and *Bubalus bubalis*) reveals distinct, species-specific morphological characteristics. These findings corroborate the foundational principles of veterinary forensics and mammalian trichology established by early pioneers such as L.A. Hausman and refined through standardized methodologies like those of Brunner and Coman (1974). Because hair shafts exhibit high resistance to chemical and environmental degradation, they serve as exceptionally reliable biological evidence in wildlife forensics, ecological surveys, and criminal investigations (Sahajpal et al., 2009; Bahuguna et al., 2010).

A comparative evaluation of the data highlights clear structural variations among the species. Carnivores such as the German Shepherd (*Canis lupus familiaris*) and the domestic cat (*Felis catus*) demonstrate unique structural traits; While the dog exhibits a transitional coronal-to-imbricate pattern with irregular wavy-crenate profiles and smooth-to-rippled margins, the cat features closely spaced, heavily toothed, imbricate scales with distinct crenate margins. These features allow for a reliable micro-morphological distinction between common domestic companion animals.

In contrast, livestock species exhibit larger-scale structural patterns influenced by their coat adaptation and physiology. The horse (*Equus caballus*) is characterized by transversely arranged, elongated imbricate scales with intermediate spacing, whereas the cow (*Bos taurus*) displays a uniform, shingle-like pattern of flattened, regularly spaced overlapping scales with crenate margins. Notably, the goat (*Capra hircus*) presents a highly diagnostic herringbone (V-shaped) configuration—an arrangement that can vary depending on regional anatomy (such as the neck, lumbar, or croup regions)—distinguishing it from the irregular, wavy, and rippled imbricate patterns observed in the water buffalo (*Bubalus bubalis*).

Ultimately, the specific variations observed in hair color, texture, scale margin morphology, inter-scale distance, and cuticular patterns confirm that hair micromorphology remains a vital tool for species identification. These diagnostic parameters not only aid in forensic investigations and the prosecution of wildlife and livestock-related crimes (Mathiak, 1938; Adorjan and Kolenosky, 1969) but also provide a solid anatomical basis for broader ecological and taxonomic research.

Conclusions

This study demonstrates the critical utility of hair micromorphology in distinguishing between various domestic mammalian species. Through detailed microscopic analysis of cuticular scale patterns, scale margins, inter-scale distances, and medullary characteristics, clear species-specific diagnostic traits were established for dogs, cats, horses, cows, goats, and water buffaloes. Features such as the distinct herringbone configuration in goats, the regular shingle-like imbricate pattern in cows, and the sharply crenate margins in cats highlight the high degree of morphological diversity among mammalian hair shafts.

Given that hair retains its structural and chemical integrity over extended periods, these findings reinforce its value as a robust biological indicator in forensic investigations, wildlife law enforcement, comparative taxonomy, and ecological studies. Integrating cuticular scale profiling with standard microscopic techniques provides a reliable, non-destructive, and cost-effective method for species identification. Future research incorporating larger sample sizes across diverse geographical regions and breeds will further expand reference databases, enhancing the accuracy of forensic and biological hair analyses.

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