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CHARACTERIZATION OF DORSAL GUARD HAIR OF THE WILD GOATS AND SHEEP (BOVIDAE: CAPRINAE) OCCURRING IN THE HIMALAYA AND WESTERN GHATS OF INDIA

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Abstract: The morphological and microscopic characteristics of dorsal guard hair of six species of the Indian goat-antelopes are described. Although the cuticular characteristics of hair of all the six species studied are similar, the morphological, medulla and transverse section characteristics of hair are varied between the species. The hair of Indian caprines can easily be identified on the basis of their unique medulla and transverse section. The high-resolution microphotographs and key characteristics of hair are presented here and can be used as an appropriate reference for species identification of the wild goats and sheep occurring in the Himalaya and Western Ghats of India.

Keywords: Argali, Bharal, caprines, Himalayan Goral, Himalayan Serow, Himalayan Tahr, Nilgiri Tahr, morphological characteristics, microscopic characteristics, tricho-taxonomy.

Tamil Abstract: இந்திய காடுகளில் வாழுகின்ற ஆறு இன காட்டாடுகளின் உடல் மேல்பகுதி ரோமத்தின் (dorsal guard hair) வெளிப்புற மற்றும் நுண்ணிய பண்புகள் ஆராய்ந்து விவரிக்கப்பட்டுள்ளது. இவ்விலங்குகளின் ரோமத்தின் கியூட்டிகிலினாது (cuticle) ஒத்த பண்புகளாக காணப்பட்டது. ஆனால் ரோமத்தின் மெடுலா (medulla) மற்றும் குறுக்குவாட்டு தோற்றம் (transverse-section) இந்த ஆறு இன காட்டாடுகளுக்கிடையே வேறுபட்டு காணப்பட்டது. இந்த தனிப்பட்ட மெடுலா மற்றும் குறுக்குவாட்டு தோற்ற பண்புகளை வைத்து இந்த ஆறு காட்டாடுகளை இன அடையாளம் கண்டறிய முடியும். இவ்விதத்தில் வழங்கப்பட்டுள்ள மிக தெளிவான நுண்ணிய பண்புகளை காட்டும் ரோமத்தின் புகைப்படங்கள் மற்றும் கண்டறியும் காரணிகள், இந்தியாவின் இமயமலை மற்றும் மேற்குத் தொடர்ச்சி மலைகளில் வாழுகின்ற காட்டாடுகளின் இனங்களை கண்டறியும் சரியான குறிப்புகளாக பயன்படுத்தலாம்.

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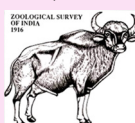
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INTRODUCTION

Both the morphological and microscopic characteristics of the hair are relatively significant in the study of mammalian species identification along with the diet-ecology and control of the illegal trade of wildlife or its derivatives (Stains 1958; Brunner & Coman 1974; Koppikar & Sabins 1976). The tricho-taxonomy (the study of mammalian hair) has been developed by many workers of the world (Hausman 1920; Mathiak 1938; Mayer 1952; Adorjan & Kolenosky 1969; Moore et al. 1974; Keogh 1983). In India, the tricho-taxonomic studies on different orders of class Mammalia: Carnivora (Chakraborty & De 2010), Primates (De 1993; Sarkar et al. 2011), and Rodentia (Bahuguna 2008) have been carried out; however, very meagre information is available on the species of wild goats and sheep (Indian caprines), except for a few studies by Bahuguna & Mukherjee (2000) (Tibetan Antelope), Sahajibal et al. (2010) (*Capra* sp.), and Kamalakannan (2018) (Takin).

As per Wilson & Reeder (2005), there are 11 species of the subfamily Caprinae under the family Bovidae distributed in the Himalaya (10 species) and Western Ghats (one species) of India, of which six species, namely Himalayan Serow *Capricornis thar* (Hodgson, 1831), Himalayan Tahr *Hemitragus jemlahicus* (C.H. Smith, 1826), Himalayan Goral *Naemorhedus goral* (Hardwicke, 1825), Nilgiri Tahr *Nilgiritragus hylocrius* (Ogilby, 1838), Argali *Ovis ammon* (Linnaeus, 1758), and Blue Sheep *Pseudois nayaur* (Hodgson, 1833) are available at the National Zoological Collections of the Zoological Survey of India (ZSI), Kolkata, India, as preserved skins.

Except for Bharal, the other species of Indian caprines are the threatened as per the IUCN Red List (2018), and are listed under Schedule I (except *N. goral* in Schedule III) of the Indian Wildlife (Protection) Act, 1972. As per CITES (2018), *C. thar* and *N. goral* are listed under the Appendix I. The aim of the study is to give a complete morphological and microscopic of characteristics of dorsal guard hair of Indian caprines for species identification.

MATERIAL AND METHODS

The dorsal guard hairs were collected from the 4–5 identified specimens of each species housed at the National Zoological Collections of Zoological Survey of India (ZSI), Kolkata, India. The hair samples were washed thoroughly with Acetone ($(\text{CH}_3)_2\text{CO}$ = 58.08) and Carbon tetrachloride (CCl_4 = 153.82) to remove

the dirt of exogenous materials. The morphological characteristics of hair ($n=20$) such as colour, number of bands, shape and length were recorded using a hand lens and dial-caliper (Mitutoyo), and the diameter of hair was measured using the digital camera fitted on an optical microscope (Olympus BX41).

To study the characteristics of cuticula, the hair samples ($n=20$) were washed with various grades (40–90 %) of acetone; the processed hairs were chopped into small pieces, placed over the clear varnish coated-microscopic glass slide; after 2–3 hours, the dried hairs were dragged gently with a fine forceps for leaving the imprint or casts of scales over the microscopic glass slide. To study the characteristics of medulla, the processed hairs ($n=20$) were chopped into small pieces and whole mounted over the microscopic glass slide with the help of D.P.X. To study the shape of transverse section, a simple hand sectioning (slicing) method was done and the slicing samples ($n=20$) were whole mounted over the microscopic glass slide with the help of D.P.X. The cuticular scale characteristics of hair such as scale position, scale patterns, structure of scale margins and distance between scale margins; the medullary characteristics of hair such as width composition, structure and form of margins of the medulla and the shape of transverse section of hair was examined under 400x magnification with the help of the digital camera fitted an optical microscope (Olympus BX41) and the observed microscopic characteristics of hair were photographed. The measurement values include minimum, maximum, average and standard deviation records.

The methods and nomenclature of morphological, cuticular, medullary and transverse sectional characteristics of hair were followed according to the descriptions provided by Brunner & Coman (1974) and Teerink (1991) and the nomenclature of colour of hair was followed as per Ridgway (1886).

RESULTS AND DISCUSSION

Morphological characteristics of hair (Table 1)

The colour of the coat and individual hair of the six species had shown different shades of brown, black and grey. Among the six species, the hair of *C. thar*, *H. jemlahicus* and *N. goral* was observed as bicoloured with two bands, whereas *N. hylocrius*, *O. ammon*, and *P. nayaur* were observed as unicoloured and unbanded. The pelage of *H. jemlahicus* and *N. hylocrius* adults are sexually dimorphic thus, male and female have distinct

Table 1. Morphological characteristics of dorsal guard hairs of Indian caprines.

Species	Coat colour	Colour of hair	No. of bands	Profile	Length (mm)	Width (μm)
<i>Capricornis thar</i>	Black to red	Bicoloured, base: cream; tip: black	2	Slightly wavy	27.9–39.6 (33.5 \pm 4.7)	59.4–217.1 (152.7 \pm 64.8)
<i>Hemitragus jemlahicus</i>	Deep copper brown (male), light brown (female)	Bicoloured, base: taupe; tip: tan	2	Undulated	11.3–45.6 (30.3 \pm 12.5)	58.3–67.2 (62.3 \pm 5.1)
<i>Naemorhedus goral</i>	Brownish-grey	Bicoloured, base: tan; tip: black	2	Slightly wavy	13.1–41.6 (29.1 \pm 11.1)	37.3–96.1 (78.2 \pm 20.4)
<i>Nilgiritragus hylocrius</i>	Blue-black grizzled with white hairs (male), greyish-brown (female)	Battleship grey	Unbanded	Undulated	13.6–38 (27.3 \pm 7.7)	36.9–130.1 (70.3 \pm 35.6)
<i>Ovis ammon</i>	Grey-brown	Wheat	Unbanded	Undulated	24.6–38.6 (30.8 \pm 4.5)	74.9–256 (182.7 \pm 79.1)
<i>Pseudois nayaur</i>	Slate blue	Beaver	Unbanded	Undulated	27.3–51.1 (42.2 \pm 7.9)	66.6–88.1 (74.2 \pm 4.4)

coat colour (Menon 2014). The shape of the hair of all the six species was observed also slightly different: *H. jemlahicus*, *N. hylocrius*, *O. ammon*, and *P. nayaur* were undulated whereas *C. thar* and *N. goral* were slightly wavy. The average length of hair of six species was ranged from 27.3mm to 42.2mm, the maximum length of hair was observed in *P. nayaur* (42.2 \pm 7.9 mm) and minimum in *N. hylocrius* (27.3 \pm 7.7 mm). The diameter of hair varied greatly from 182.7 \pm 79.1 μm as a maximum in *O. ammon* and 62.3 \pm 12.5 μm as a minimum in *H. jemlahicus*.

The specific morphological characteristics of hair (Table 1) preliminarily distinguish the six species studied. Teerink (1991) reported that the straight and undulated types of hair are one of the features of hair of bovids and according to Koppikar & Sabins (1976) and De & Chakraborty (2013), the species of the family Bovidae may be identified by their combination of physical and microscopic characteristics of hair.

Cuticular scale characteristics of hair (Table 2; Image 1–6a)

Among the six caprine species, the cuticular scale characteristics show no variations among the species and were observed as the scale position - 'transversal', scale patterns - 'regular wave', structure of scale margins - 'smooth' ('rippled' in *N. goral*) and the distance between scale margins - 'near'. The measurement values of cuticular scales of hair show great variations between the species, average scale count per millimetre length of hair were observed as maximum in *N. hylocrius* (276.5 \pm 20.1 μm) and minimum in *P. nayaur* (113.6 \pm 23.2

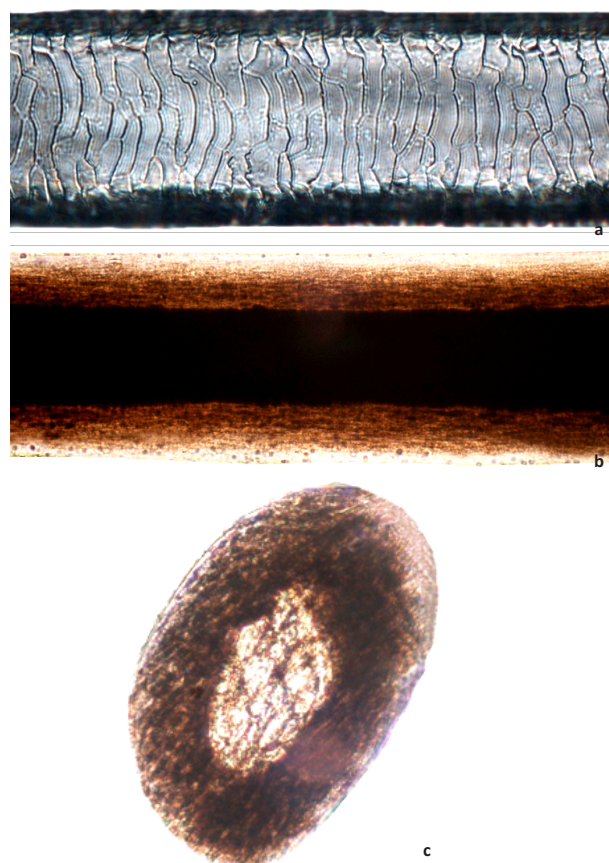


Image 1. Microscopic characteristics of dorsal guard hair of *Capricornis thar*. (a) cuticle (400x), (b) medulla (400x), (c) transverse section (400x). © M. Kamalakannan.

μm). The average length of scale of hair vary greatly from 137.1 \pm 2.1 μm as a maximum in *O. ammon* and 55.2 \pm 3.2



Image 2. Microscopic characteristics of dorsal guard hair of *Hemitragus jemlahicus*. (a) cuticula (400x), (b) medulla (400x), (c) transverse section (400x). © M. Kamalakannan.



Image 3. Microscopic characteristics of dorsal guard hair of *Naemorhedus goral*. (a) cuticula (400x), (b) medulla (400x), (c) transverse section (400x). © M. Kamalakannan.

μm as a minimum in *C. thar*. Similarly, the maximum and minimum scale width of hair range was recorded in *O. ammon* ($17.1 \pm 3.2 \mu\text{m}$) and *C. thar* ($7.4 \pm 1.5 \mu\text{m}$), respectively.

Although the cuticular scale characteristics are almost similar in all the six species studied, the measurement values can be considered for species identification. According to Chakraborty & De (2010) the cuticular scale values along with the other combination of characteristics of hair should be taken for species identification, if the cuticular scale characteristics of hair are same between the species.

Medullary characteristics of hair (Table 2; Image 1–6b)

The medullary characteristics of hair show substantial variations among all the six species studied. The composition of the medulla was observed as 'multicellular in rows' in all species except in *C. thar* ('unicellular regular'). The structure of the medulla is 'wide medulla lattice' in *H. jemlahicus*, *O. ammon* and *P. nayaur*; 'simple' in *C. thar*, 'wide aeriform lattice' in *N. goral*, and 'reversed cloisonné' in *N. hylocrius*. The form of the medulla margins observed as 'straight' in all

species except in *N. hylocrius* ('scalloped'). The average width of the medulla also varies considerably from $120.8 \pm 2.1 \mu\text{m}$ as a maximum in *P. nayaur* and $42.5 \pm 1.6 \mu\text{m}$ as a minimum in *N. hylocrius*. The medulla of hair of the six species illustrate the different characteristics for identification of the species.

Transverse section of hair (Table 3; Image 1–6c)

The shape of the transverse section of hair shows variations among all the six species studied and was observed as an 'oval' shape in *C. thar* and *N. goral*, 'circular' in *P. nayaur*, 'biconvex' in *N. hylocrius* and *O. ammon*, and 'dumb-bell' in *H. jemlahicus*. The transverse section of hair of *O. ammon* ('biconvex') and *P. nayaur* ('circular') only determines the species identity among the six species in particular, as other characteristics are similar between the species. Dharaia & Soni (2012) found in their study that the shape of the transverse section is one of the important characteristics for hair identification of the species.

Key characteristics of hair to identify the species

Apart from the morphological characteristics and

Table 2. Cuticular scale characteristics of dorsal guard hairs of the Indian caprines.

Species	Scale position	Scale patterns	Structure of scale margins	Distance between scale margins	Scale count/mm length of hair	Length of scale (µm)	Width of scale (µm)
<i>Capricornis thar</i>	Transversal	Regular wave	Smooth	Near	164–256 (187.5±24.2)	50.6–58.9 (55.2±3.2)	4.1–9.7 (7.4±1.5)
<i>Hemitragus jemlahicus</i>	Transversal	Regular wave	Smooth	Near	159–200 (177.2±10.4)	70.2–79.8 (75.4±3.2)	9.7–13.9 (10.7±2.2)
<i>Naemorhedus goral</i>	Transversal	Regular wave	Rippled	Near	108–146 (127.6±11.4)	85.1–98.5 (90.4±4.1)	10.6–20.5 (14.9±2.8)
<i>Nilgiritragus hylocrius</i>	Transversal	Regular wave	Smooth	Near	254–320 (276.5±20.1)	96.0–125.0 (112.1±11)	6.9–17.4 (12.3±3.1)
<i>Ovis ammon</i>	Transversal	Regular wave	Smooth	Near	96–152 (118.5±17.6)	134.1–140.1 (137.1±2.1)	13.9–23.7 (17.1±3.2)
<i>Pseudois nayaur</i>	Transversal	Regular wave	Smooth	Near	87–162 (113.6±23.2)	83.1–95.1 (87.5±3.7)	11.1–20.3 (14.2±2.6)

Table 3. Medullary characteristics and shape of cross-section of dorsal guard hairs of the Indian caprines.

Species	Composition of medulla	Structure of medulla	Margins of medulla	Width of medulla (µm)	Shape of transverse section
<i>Capricornis thar</i>	Unicellular regular	Simple	Straight	98.6–116 (107.7±5.3)	Oval
<i>Hemitragus jemlahicus</i>	Multicellular in rows	Wide medulla lattice	Straight	90.2–123 (103.4±9.9)	Dumb-bell
<i>Naemorhedus goral</i>	Multicellular in rows	Wide aeriform lattice	Straight	76.1–90.1 (85.1±4.9)	Oval
<i>Nilgiritragus hylocrius</i>	Multicellular in rows	Reversed cloisonné	Scalloped	40.4–46.3 (42.5±1.6)	Biconvex
<i>Ovis ammon</i>	Multicellular in rows	Wide medulla lattice	Straight	72.3–79.5 (76.4±2.5)	Biconvex
<i>Pseudois nayaur</i>	Multicellular in rows	Wide medulla lattice	Straight	117.5–124.3 (120.8±2.1)	Circular

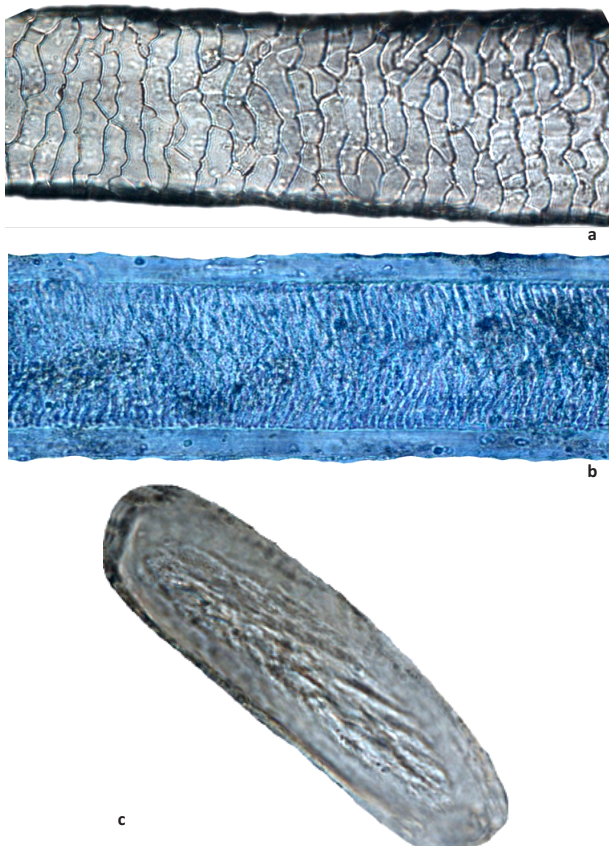
Image 4. Microscopic characteristics of dorsal guard hair of *Nilgiritragus hylocrius*. (a) cuticle (400x), (b) medulla (400x), (c) transverse section (400x). © M. Kamalakannan.

Table 4. Key characteristics of hair to identify the species.

Species	Key characteristics
<i>Capricornis thar</i>	Composition of medulla - unicellular regular; structure of medulla - simple; transverse section - oval
<i>Hemitragus jemlahicus</i>	Structure of medulla - wide medulla lattice; transverse section - dumb-bell
<i>Naemorhedus goral</i>	Structure of scale margins - rippled; structure of medulla - wide aeriform lattice; transverse section - oval
<i>Nilgiritragus hylocrius</i>	Structure of medulla - reversed cloisonné; margins of medulla - scalloped; transverse section - biconvex
<i>Ovis ammon</i>	Transverse section - biconvex
<i>Pseudois nayaur</i>	Transverse section - circular

measurement values of cuticular scale and medulla of the hair, the following important key characteristics may help to identify the species of Indian caprines correctly (Table 4).

Caprines are highly trafficked in the illegal trade after carnivores, used mainly for local bushmeat consumption, and for their skin and other derivatives (Menon & Kumar 1999). On the other hand, they are the chief prey to the large carnivores (Menon 2014). Therefore, the identification keys along with high-resolution microphotographs presented here may be used in animal forensic science as well as food-habit analysis of predator, as an appropriate reference for species identification of Indian caprines.



Image 5. Microscopic characteristics of dorsal guard hair of *Ovis ammon*. (a) cuticula (400x), (b) medulla (400x), (c) transverse section (400x). © M. Kamalakkannan.

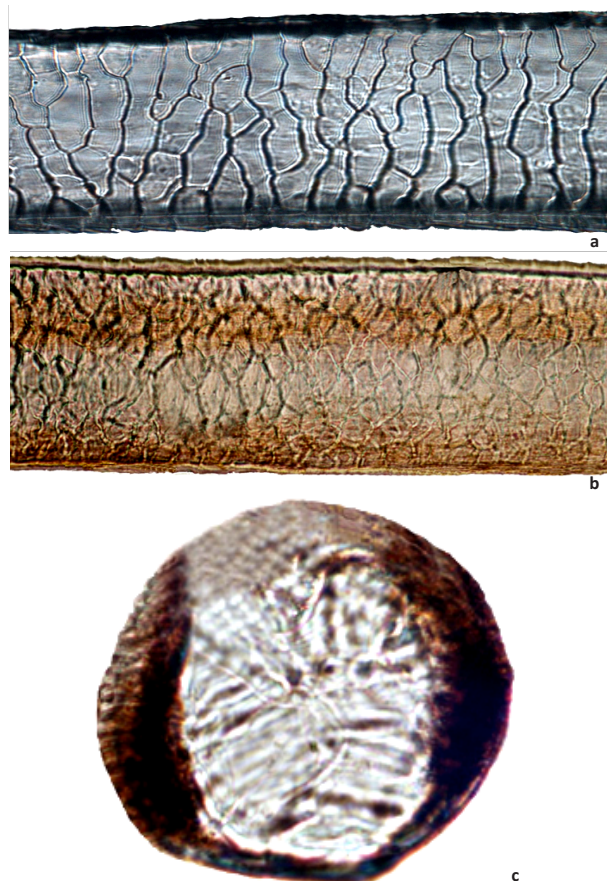


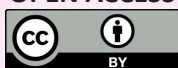
Image 6. Microscopic characteristics of dorsal guard hair of *Pseudois nayaaur*. (a) cuticula (400x), (b) medulla (400x), (c) transverse section (400x). © M. Kamalakkannan.

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