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Pelage insulation in mustelids
: Hair density and morphology of medulla in mustelids

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1. Abstract

Pelage insulation depends on the density and length of hair. Hair density is an important factor for determining the quality of fur and to help mammals adapt to their habitat. This study measured hair density and observed the morphology of the medulla in pelage of Japanese mustelids. Hair density was calculated from the number of hairs per hair bundle and the number of hair bundles per cm^2. Morphological observations of the medulla were made with a scanning electron microscope (SEM). The hair density was highest in the sea otter (*Enhydra lutris*), followed by the river otter (*Lutra lutra*), the mink (*Neovison vison*), the ermine (*Mustela earminea*), the sable (*Martes zibellina*), the Japanese weasel (*Mustela itatsi*), and the least weasel (*Mustela nivalis*). The morphology of the medulla varied more than expected. This suggests that the medulla morphology could be used to identify a species in mammals. This study suggests the possibility for clarifying whether hair density and the morphology of the medulla depend upon taxonomy or habitat, by examining the pelage of species inhabiting different environments.

2. Introduction

Pelage insulation depends upon its volume, that is, the density and length of hair. Therefore, fur breeders have been interested in hair density as an important factor for determining the quality of fur. The hair densities of the sheep (*Ovis aries*), the northern fur seal (*Callorhinus ursinus*), and the beaver (*Caster canadensis*) are known[1]. However, not many studies, concerning mammals other than the mink (*Neovison vison*) and the fox (*Vulpes vulpes*), indicate how to measure hair density[2], which have been favorably received and appreciated[3),4)].

Many of the studies on hair density, thus far, were conducted from the perspective of people who use fur for warmth and there have not been many studies from the viewpoint of the significance for the mammals. This study measured the hair density of Japanese mustelids based on an adapted version of the hair density measurement methods. I also observed the morphological structure of the medulla of guard hair which may be related to the insulation of the pelage and the habits of mammals[5].

Finally, the hair density and morphology of the medulla were discussed in relation to the habitats of mammals.

3. Materials and methods

The winter skin samples, used for measuring the hair density and observing the medulla, were collected from the following species; the sable (*Martes zibellina*), the least weasel (*Mustela nivalis*), the ermine (*Mustela earminea*), the Japanese weasel (*Mustela itatsi*), the mink (*Neovison vison*), the river otter (*Lutra lutra*), and the sea otter (*Enhydra lutris*).

Skin specimens of (approx. 1 cm^2) for the observation were taken from the dorsal side of the skin, close to the tail. The specimens were soaked in a detergent for 24 hours and then dehydrated using ethanol.

1) Measuring the hair density

Hair density was determined according to previously applied methods[2]. The hair on the specimens, cut from the skin samples, were first sheared, and then the number of hair bundles (HB) per unit area (2.5 mm × 2.5 mm) were counted at 10 places on the surface of each specimen using a stereomicroscope with a micrometer. Additionally, each skin specimen was sectioned perpendicularly to the backbone, and the number of hairs per hair bundle (H) were measured using a scanning electron microscope (SEM). After these measurements, the hair density (the number of hairs/cm^2, HD) was calculated from the following formula: $HD = H \times HB/cm^2$.

2) Observations of the hair medulla

Observations of the hair medulla with SEM were made according to previously applied methods[6]. First, guard hairs taken from each fur skin sample were attached onto brass standard stubs with scotch tape, after which a razor blade was used to cut along the axis of the fiber under the stereomicroscope. The prepared stubs were coated with gold using an ion-spattering apparatus. Observations were made with a JSM-T220 SEM at 15Kv.

4. Results

1) Hair density

The examples of the hair bundle used to calculate the density are shown in Fig. 1, which are the hair bundles of a sable and sea otter sample. In the hair bundle of the sable (A), one guard hair and 14 underfurs were observed. In the

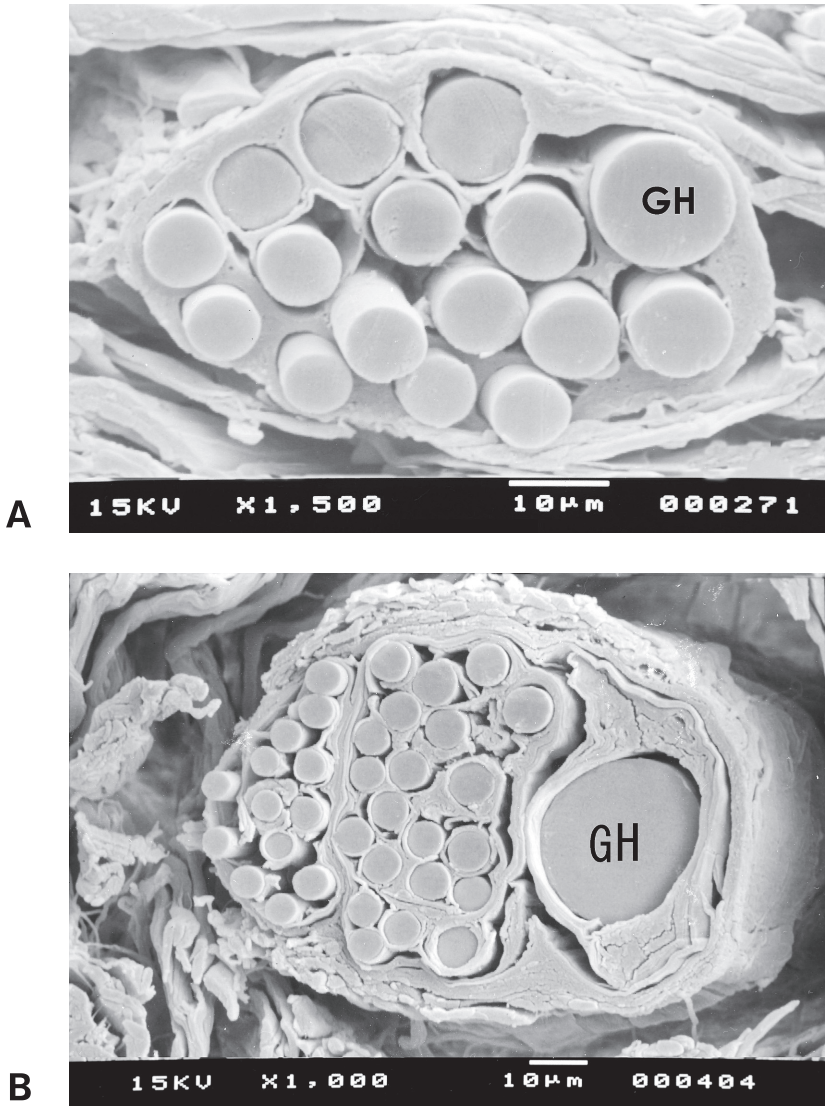


Fig. 1 SEM features of hair bundles
A. Hair bundle of the sable (*Martes zibellina*) composed of one guard hair (GH) and 15 underfurs.
B. Hair bundle of the sea otter (*Enhydra lutris*) composed of one guard hair (GH) and 33 underfurs

Table 1. Number of hair/bundle, number of bundles/cm^2 and hair density.
The average with the standard deviation (n=10) are given for hairs and bundles.

	Number of hairs/bundle X±SD	Number of Bundles/cm^2 X±SD	Hair density /cm^2
Sable	12.4±1.25	1,037±128.7	12,860
Least weasel	8.2±0.96	687± 52.8	5,630
Ermine	12.1±1.32	1,450± 69.3	17,550
Japanese weasel	17.4±0.96	727± 69.3	12,650
Mink	26.3±1.12	1,283± 52.8	33,720
River otter	34.2±0.71	1,714±108.9	58,600
Sea otter	34.1±0.77	4,520±303.6	154,100

sea otter hair bundle (B), one guard hair and 36 underfurs were found.

The number of hairs per hair bundle, the number of hair bundles per cm^2, and the hair density are shown in Table 1.

The hair density was high in the sea otter, the river otter and the mink (Table 1). The hair densities of the sable, the ermine and the Japanese weasel were much lower than those in the first group. The hair density of the least weasel was very low compared to those of the other mustelids used in this experiment.

2) Morphology of the medulla

The morphology of the medulla, observed with SEM, is shown in Fig. 2.[7].

In the medulla of the sable, the air spaces (As) were the largest among mustelid samples used in this experiment. These air spaces were mostly circle like polygon shape or oval. Among these air spaces, small air spaces (Sp) separated in cancellous sectors were observed (Fig. 2-A).

In the ermine, the air spaces were smaller than those of the sable, but they were similar in shape, which was circle-like polygon, flat or oval. However, small cancellously air spaces were not observed (Fig. 2-B).

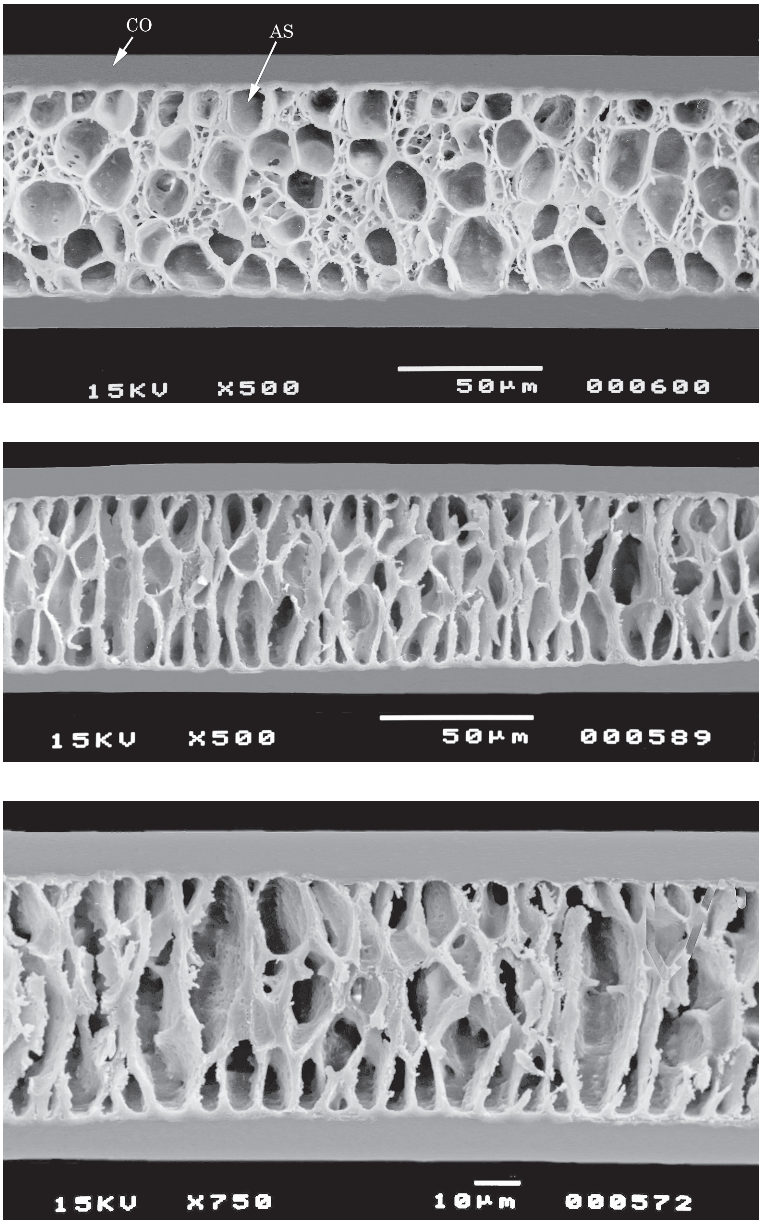
In the medulla of the least weasel, the oval air spaces found in the ermine were of a more flattened shape (Fig. 2-C).

In the Japanese weasel, the air spaces were more flattened than those of the least weasel but they were neither polygon nor oval-shaped air spaces as a whole (Fig. 2-D).

In the medulla of the mink, polygon-shaped air spaces were observed, unlike those of the Japanese weasel. Their shapes were more like those of sables and ermines (Fig. 2-E).

The medulla of the river otter, with ladder shaped air spaces, was very different from that of the sable and the Japanese weasel. Additionally, it was observed that the proportion of the medulla (diameter of medulla/diameter of whole fiber) was lower than those of the other mustelids, except for the sea otter (Fig. 2-F).

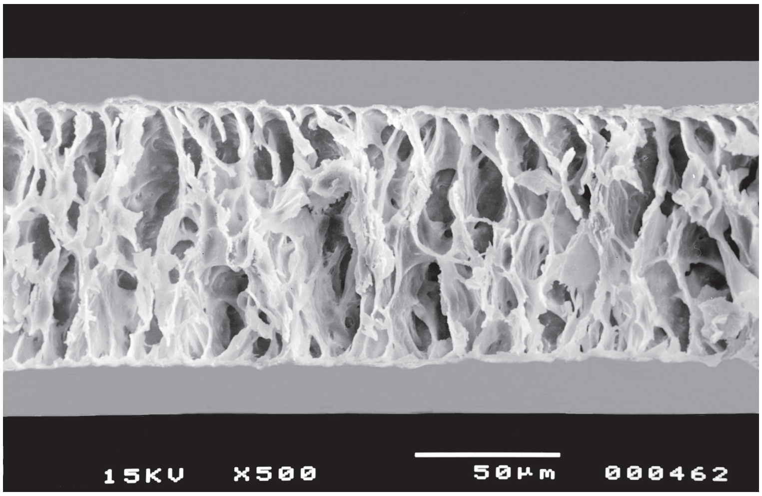
Air spaces in the medulla of the sea otter were much more ladder- shaped than those of river otters. The proportion of the medulla was even lower than that of the river otter (Fig. 2-G).



A

B

C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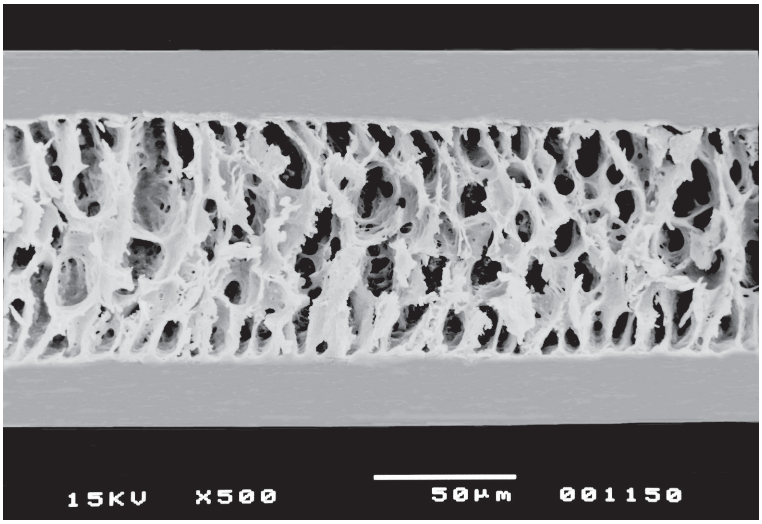
D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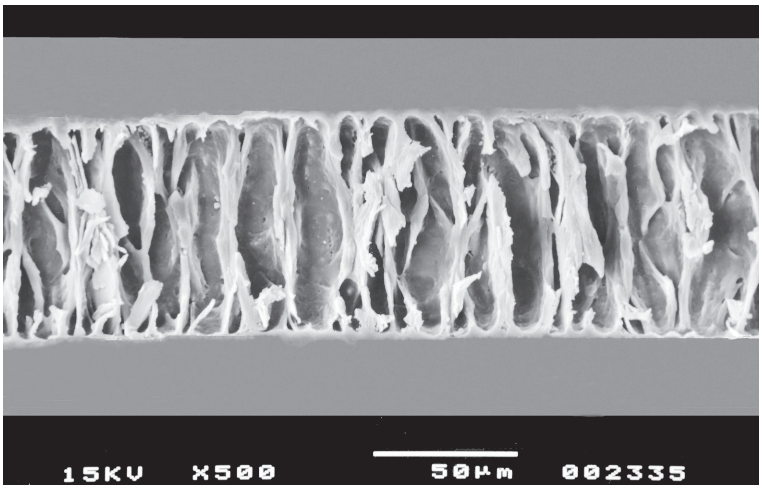
E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F

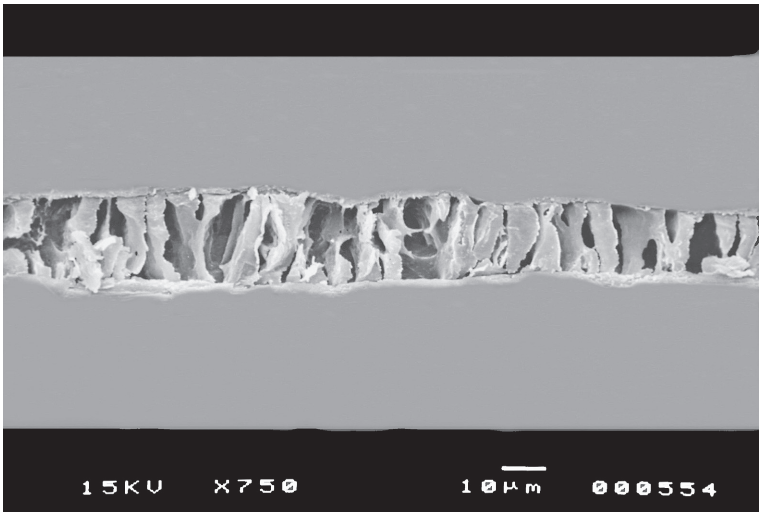
G 

Fig. 2 SEM features of medulla sectioned longitudinally.
A. Sable (*Martes zibellina*), **B.** Ermine (*Mustela earminea*)
C. Least weasel (*Mustela nivalis*)
D. Japanese weasel (*Mustela itatsi*)
E. Mink (*Neovison vison*), **F.** River otter (*Lutra lutra*)
G. Sea otter (*Enhydra lutris*)
Co: hair cortex As: airspace

5. Discussion

Table 1 shows that the hair density depends upon the number of hairs per hair bundle and hair bundles per unit area. The samples that showed a high density, such as the sea otter (approx. 150,000/cm^2), the river otter (approx. 60,000/cm^2), and the mink (approx. 30,000/cm^2), have many hairs per hair bundle. Therefore, hair density depends more on the number of hairs per hair bundle. The number of hairs per hair bundle of the ermine was almost the same as that of the sable, but the hair density was higher in the ermine than in the sable. The difference in the number of bundles per unit area made the hair density of the ermine higher than the sable. This contradicts the above-mentioned tendency. Future observations including measurements of the hair length and proportion of the medulla in each hair of the ermine and the sable are needed to clarify the relationships among insulation, habitat, and taxonomy.

Hair density differs among individuals in the same species[2),8)]. Therefore, the hair densities measured in this experiment are not absolute but approximate figures. However, the high hair densities measured in the river and sea otter may be their characteristics. The river and sea otter are aquatic in mustelids, which are normally terrestrial. Therefore, in mustelids, the more aquatic the species is, the higher the hair density will be. This may also explain why a higher hair density was observed in the mink than in the sable or the other terrestrial mustelids species.

It is interesting that the hair density of the least weasel was very low among the mustelids used in this experiment. The hair density level may reflect the mammal's habitat, as hairs act as an insulator to maintain their body temperature. This experiment used only one body of the least weasel, so it may be too early to conclude, but it can be assumed that the life of the least weasel in winter may be distinct from other terrestrial mustelids. A comparison among individuals from different habits is expected to verify this, but hair density may be relevant for surmising the unknown life form of mammals.

The author has pointed out that mammals with a lower proportion of the medulla in hair are more aquatic[5]. As the medulla is composed of air spaces, which take in air, a low proportion of the transverse section occupied by the medulla means poor heat insulation. Therefore, it may be assumed that aquatic mammals, whose insulation is low because of their hair structure, adapt themselves to the environment with a high hair density.

Morphology of the medulla is regarded as key to identifying species based on cuticles, the surface structure of hair[9,10,11]. In the past, studies on the morphology of hairs were observed under a light microscope. The author of this paper used SEM to observe the morphology of hairs and clarified that the relationships between mammal classification and the morphology of the medulla in guard hairs agree well at the family level[5,6]. Fig. 2 shows that the morphology of the medulla varies more than expected. More specifically, in mustelids, the morphology of the medulla observed with SEM can be used to identify the species. In addition, measurements of the proportion of the medulla, using a light microscope, may be useful in identifying hair[12]. Therefore, a combination of observations with SEM and a light microscope will increase the accuracy of identification.

Cuticles, which constitute the outermost layer of hair, are vulnerable to damages caused by various factors. Therefore, it would be fairly difficult to identify the species based on the cuticle observation, when the hairs were stored for a long time, or taken from feces or alimentary canals. Moreover, the medulla, the inner component of hair, is not vulnerable to damages and usually maintains its structures. In this regard, observations of the morphology of the medulla would be useful in identifying species using hair.

Pelage is important for mammals to adapt themselves to the environment. Even in Japanese mustelids, each species inhabits various environments. This study suggests a possibility for clarifying whether hair density and the medulla depend upon taxonomy or habitat by examining multiple skins from different individuals inhabiting different environments.

6. References

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