

Morphometric characteristics of the hair coat of ancient dog breeds*

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The aim of this study was to characterize and compare morphometric parameters of the hair coat of selected ancient dog breeds, the Czechoslovakian Wolfdog, the German Shepherd, and the wolf. The following guard hair and wool hair parameters were measured: length, diameter of proximal, distal and intermediate parts, and thickness of the cortex. Analysis of variance showed that breed (species) is a statistically significant factor for most of the traits studied, in the case of both guard hair and undercoat. The exception was the diameter of the central part of the undercoat, where analysis of variance showed no effect of breed. The results of the measurements of individual hair characteristics were highly varied. This is due to the large number of dog breeds, whose coats have radically different parameters. The most variable feature between breeds (species) was hair length. The data were used to create a dendrogram showing the differences in the parameters of the coats of the different dog breeds and the wolf. It shows that the greatest similarity is between the Lhasa Apso and the Samoyed, while the furthest from these are the German Shepherd, Akita, Czechoslovakian Wolfdog and wolf. The analyses showed no significant differences between the coat of the German Shepherd and the wolf, despite the fact that the German Shepherd is not classified as an ancient breed and of all the breeds studied is the most genetically distant from its wild ancestor. The study clearly demonstrates that the coat characteristics were subject to inheritance that does not reflect the phylogenetic distance between the wolf and ancient breeds.

KEY WORDS: fur coat / dog / ancient dog breeds / wool hair / guard hair

The domestic dog (*Canis familiaris* L.) is an unusual example of variation in breeds achieved through domestication. However, the evolutionary processes underlying the genesis of this diversity are poorly understood. In research on the origin of the dog, varying theories have emerged as to where and how it was domesticated and the species from which it derives. Due to their similarity and ability to crossbreed, the wolf, jackal and

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coyote have been suggested as ancestors of the dog. However, genetic, morphological and behavioural studies indicate that the domestic dog derives from the wolf [1, 10, 12]. It is very likely that domestication took place independently during different periods and in different geographic regions. Furthermore, genetic material may have been exchanged between already domesticated dogs and wild wolves [10]. Thus far no consensus has been reached on the geographic region where the species was domesticated. Studies using DNA from dogs and wolves from various regions of the world have named East Asia or the Middle East as the most likely site of domestication [6, 11].

In 2004, the results of research using molecular markers were published. Among the 85 dog breeds analysed, 14 ancient breeds were identified, i.e. those whose genetic material differs the least from wolf genes [5].

Over 350 dog breeds are currently recognized worldwide, varying considerably in their morphology, physiology and behaviour. They were obtained as a result of thousands of years of breeding work. For this reason dogs exhibit phenotypic variability greater than that of any other mammal [7]. For example, the height measured at the withers ranges from about 20 cm in the Chihuahua to over 80 cm in the Great Dane; the coat colour varies from white to grey, brown and black; and the hair coat may be short or long, with straight or curly hair [3].

In the hair coat of the dog, wolf, and many other mammalian species we can distinguish the guard hair and wool hair. The coat consists of hairs varying in length, thickness and microscopic structure [4]. The features of the hair coat are determined by multiple genes inherited independently or together [8].

The aim of the study was to characterize the morphometric parameters of the hair coat of selected ancient dog breeds, as well as the Czechoslovakian Wolfdog, the German Shepherd and the wolf, and to compare the differences between them with the genetic distance determined on the basis of molecular research.

Material and methods

Hair samples taken from representatives of ten of the fourteen ancient dog breeds (Afghan Hound, Chow Chow, Lhasa Apso, Shar Pei, Shih Tzu, Basenji, Akita, Samoyed, Siberian Husky and Alaskan Malamute) were used in the study. For further comparison we also chose the wolf, as the wild ancestor of the dog, the Czechoslovakian Wolfdog, as a cross between the German Shepherd and the wolf, and the German Shepherd, as a breed which is phylogenetically distant but phenotypically similar to the wolf. The research material was obtained at national breed shows, as well as from private owners of ancient breeds or breeders of purebred dogs. Due to lack of availability or the owners' refusal, we were unable to obtain hair samples from four breeds originally in our sphere of interest (Pekingese, Tibetan Terrier, Persian Greyhound and Shiba Inu). Wolf hair was collected and sent to us by the staff of the Experimental Station in Stobnica, belonging to the Poznań University of Life Sciences.

The study material consisted of guard hair and wool hair collected from dogs and wolves from three topographical regions: the neck, back, and hindquarters. The exception was the Shar Pei, which has no undercoat. The following measurements were taken of the hair:

- total hair length (cm)
- diameter of proximal part (μm)
- diameter of central part (μm)
- diameter of distal part (μm)
- cortex thickness (μm)

The length of the guard hair and wool hair was measured to within 1 mm. Then the hair was placed under a Bresser microscope, under a 10x ocular lens and a 5x objective lens. A video track was used to transfer the image to a computer monitor, where it was recorded in the form of a graphic file. The image was opened in Makroaufmassprogramm software, which was used to perform measurements of the hairs.

Statistical analysis of the data was performed in Statistica 9.1 software [9]. Means and standard deviations of the measurements were calculated, analysis of variance of the traits was performed, and the Tukey test was used for detailed comparisons of the breeds. A cluster analysis of the data was used to create a dendrogram illustrating the differences in hair-coat parameters in the dog breeds and wolf.

Results and discussion

One-way analysis of variance was performed for each of the hair parameters tested. The results show that breed (species) is a factor with a statistically highly significant ($p < 0.01$) influence on most of the parameters analysed, for both guard hair and wool hair (Tables 1 and 2). The only exception was the diameter of the central part of the wool hair, as no influence of the breed (species) on the trait was shown.

The Tukey test, which was performed for all tested characteristics, showed statistically significant differences in the length of the guard hair and wool hair between the dog breeds and the wolf.

Analysis of the diameter of the base of the guard hair revealed statistically significant differences mainly between the wolf and the dog breeds, except for the Shih Tzu, Czechoslovakian Wolfdog and Akita. The Akita differed from the other breeds, except for the Shih Tzu, Czechoslovakian Wolfdog, Chow Chow and the wolf. Statistically significant differences for this trait were also found between the Czechoslovakian Wolfdog and both the Siberian husky and the Afghan Hound.

For the diameter of the base of the down hair, the Tukey test showed statistically significant differences between the Shih Tzu and all other breeds, as well as between the Alaskan Malamute and the German Shepherd, Shih Tzu, Czechoslovakian Wolfdog and Lhasa Apso.

The most numerous differences for the diameter of the central part of the guard hair were found for the Czechoslovakian Wolfdog, which did not differ only from the German

Table 1
Characteristic of guard hair

Breed (Species)	N	Length (cm)	SD	Diameter of proximal part (µm)	SD	Diameter of intermediate part (µm)	SD	Diameter of distal part (µm)	SD	Cortex thickness (µm)	SD
Ger. Shepherd	90	6.82	2.03	37.12	15.70	33.44	14.06	73.98	13.89	11.09	5.96
Shih Tzu	18	5.83	0.80	38.94	8.83	17.78	5.63	–	–	9.64	1.22
Czech. Wolfdog	18	6.91	0.71	42.26	11.50	43.02	16.14	90.01	17.02	14.58	6.10
Shar Pei	18	1.43	0.31	30.22	10.81	24.87	13.77	49.04	20.45	8.43	4.60
Chow Chow	18	7.98	1.78	31.74	10.04	18.67	4.78	36.83	12.47	10.01	2.34
Siberian Husky	18	4.77	0.87	26.55	8.76	17.02	6.14	49.92	19.87	9.52	3.87
Samoyed	18	8.54	2.08	30.86	15.50	21.43	8.28	46.40	17.82	7.96	4.63
Basenji	18	2.22	0.17	27.76	6.55	28.65	12.70	55.28	19.09	8.99	3.15
Akita	36	6.68	0.92	47.79	17.77	37.22	12.04	72.89	17.43	13.19	5.59
Lhasa Apso	18	10.33	2.30	32.49	8.09	22.73	7.64	47.31	8.44	10.42	4.14
Afghan Hound	18	7.52	2.57	25.31	9.30	18.20	3.01	44.70	12.86	7.34	4.10
Al. Malamute	36	6.58	1.23	34.65	11.89	28.27	9.86	60.73	13.32	10.65	4.65
Wolf	48	8.95	1.69	53.07	10.36	36.51	8.98	87.53	14.37	11.40	3.28
Total/Mean	372	6.78	2.58	37.65	15.09	29.42	13.28	65.96	21.91	10.67	4.94

Table 2
Characteristic of wool hair

Breed (Species)	N	Length (cm)	SD	Diameter of proximal part (μm)	SD	Diameter of intermediate part (μm)	SD	Diameter of distal part (μm)	SD	Cortex thickness (μm)	SD
Ger. Shepherd	90	3.68	1.28	26.19	9.01	16.36	6.74	37.96	15.19	9.07	4.17
Shih Tzu	18	2.58	0.47	37.50	6.80	16.12	6.52	42.57	9.20	9.80	2.75
Czech. Wolfdog	18	4.83	0.38	29.05	11.05	15.92	5.42	47.93	19.45	10.87	6.49
Shar Pei	–	–	–	–	–	–	–	–	–	–	–
Chow Chow	18	7.88	1.18	22.71	2.01	16.30	2.56	25.76	2.04	9.32	0.84
Siberian Husky	18	3.88	0.44	25.55	3.16	15.43	4.55	28.99	2.22	9.22	3.23
Samoyed	18	6.84	0.76	23.18	4.21	17.62	3.85	33.53	11.07	9.19	2.24
Basenji	18	1.73	0.30	26.40	4.90	16.34	2.22	34.16	5.18	6.65	1.41
Akita	36	4.32	0.46	22.69	7.37	16.82	4.40	33.74	7.98	6.49	2.11
Lhasa Apso	18	5.79	1.77	26.96	4.53	17.37	2.59	33.72	3.92	7.97	1.84
Afghan Hound	18	4.03	1.16	24.93	6.17	15.14	2.40	34.41	13.45	8.52	2.68
Al. Malamute	36	4.63	0.70	18.93	5.78	13.28	4.36	25.74	5.95	5.90	2.07
Wolf	48	4.05	1.03	22.38	5.93	16.63	7.56	36.65	13.26	6.38	1.85
Total/Mean	354	4.31	1.64	24.92	7.91	16.10	5.51	34.96	12.66	8.07	3.42

Shepherd, Akita and wolf. Numerous differences were noted for the Akita, which did not differ from the German shepherd, Czechoslovakian Wolfdog, Basenji or wolf. Statistically significant differences were found between the diameter of the central part of the guard hair of the German Shepherd and wolf and that of the Shih Tzu, Chow Chow, Siberian Husky, Samoyed and Afghan Hound. In addition, the wolf differed from the Lhasa Apso.

For the diameter of the tip of the wool hair, statistically significant differences were found between the Czechoslovakian Wolfdog and most of the breeds (except the German Shepherd, the Shih Tzu and the wolf). Statistically significant differences were also found between the Afghan Hound and the German Shepherd, Czechoslovakian Wolfdog and Shih Tzu and between the Chow Chow and Shih Tzu.

The Tukey test showed statistically significant differences ($p < 0.05$) between the cortex thickness of the guard hair of the Czechoslovakian Wolfdog and that of the Shar Pei, Samoyed, Basenji and the Afghan Hound. For down hair cortex thickness, statistically significant differences were found between the Czechoslovakian Wolfdog and the Basenji, Akita, Alaskan Malamute and wolf. In addition, statistically significant differences were noted between the German Shepherd and Akita; between the Alaskan Malamute and German Shepherd, Shih Tzu and Chow Chow; and between the wolf and the German Shepherd and Shih Tzu.

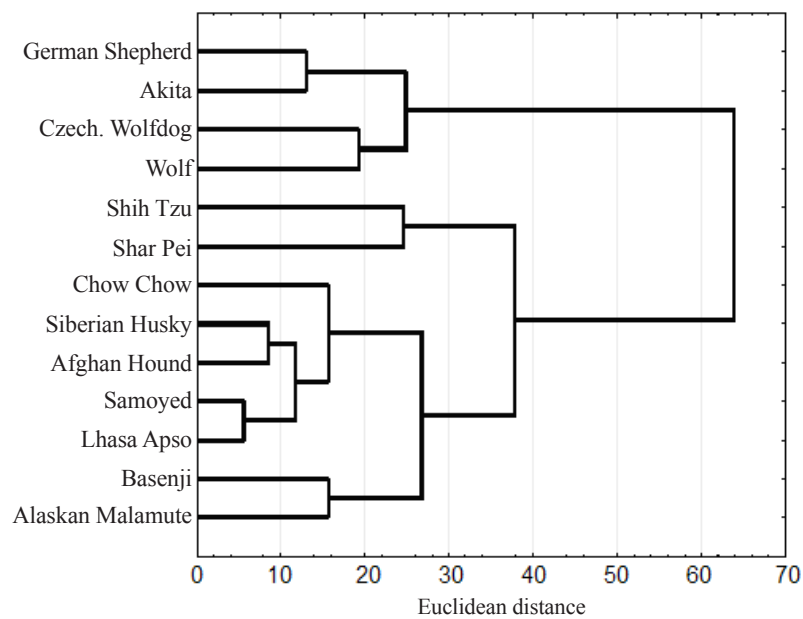


Fig. Cluster analysis incorporating morphometric parameters of hair for ancient breeds of dogs, the wolf, the German Shepherd and the Czechoslovakian Wolfdog

Analysis of the variation in the hair parameters of individual breeds and the wolf revealed considerable differences between them. This is due to the multitude of dog breeds, with hair coats having extremely varied parameters. The parameter that showed the most variation between breeds in our study was the length of the hair – both guard hair and wool hair.

The structure of the dog's coat is known to be determined by multiple genes located in various loci, as described by Sponenberg and Rothschild [8]. The data collected were used to create a dendrogram showing the differences in the hair coat of the dog breeds tested and the wolf (Fig.). It shows the greatest similarity between the Samoyed and Lhasa Apso, while the German Shepherd, Akita, Czechoslovakian Wolfdog and the wolf are located at the greatest distance from them.

However, the analysis of the hair coat characteristics does not fully reflect the genetic distance between the breeds and the wolf as described by Parker et al. [5].

In the case of the diameter of the guard hair, the Czechoslovakian Wolfdog was the most different from the others. This feature was consistent with the World Canine Organization (FCI) classification and the list given by Parker et al. [5]. The Czechoslovakian Wolfdog is not one of the ancient breeds, although it is well known to have descended from the wolf [2].

In conclusion, the results clearly indicate that the features of the hair coat were subject to inheritance that does not reflect the phylogenetic distance between the wolf and the breeds studied. The analyses showed no significant differences between the hair coat of the German shepherd and that of the Akita, Czechoslovakian Wolfdog or wolf, despite the fact that the German Shepherd is not considered an ancient breed and among the breeds analysed it is the most genetically distant from its wild ancestor.

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