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Identification value of dog (*Canis lupus familiaris*) and cat (*Felis catus*) hair based on selected features of morphology in the context of forensic examinations

Summary

Theoretical assumptions of this the work present the range of selected morphological features of the dog (*Canis lupus familiaris*) and cat (*Felis catus*) hair. The practical part consisted in morphological analysis of 270 samples of dog and cat hair recovered during an investigation conducted in the territory of Cracow by the local Prosecutor's Office. For this purpose, microscopic slides were made and analysed under an optical microscope for: colour, life cycle phase, shape of the medulla and the end of hair. Analysis of the results from the part dedicated to the examination allows answering the question whether microscopic analysis of dog and cat hairs based on selected morphological features allows identification of species.

Key words: hair, morphology, forensic science

Introduction

One of the first forensic reports concerning analysis of hair for the needs of justice system was published in France, in 1857 (Sachs, 1997). That year can be regarded as the beginning of this field of knowledge referring to forensic value of hairs that have continued to develop until the present day. During the investigation, scientists work with a variety of materials that may be used for forensic purpose, including biological traces. What is more, animal hair proved useful in archive cases because it is resistant to many destructive factors, as well as the process of body decay. In addition to that, based on morphological analysis, genus and species identification of animals is carried out in cases of poaching, smuggling of animals and illegal possession of animal products protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). One of the most important national studies in this area was devoted to quality management systems in hair examination (Włodarczyk et al., 2009). In 2015, the European Network of Forensic Institutes (ENFSI) also issued recommendations for microscopic examination and comparison of human and animal hair (ENFSI, 2015).

Modern examination techniques, such as scanning electron microscopy (SEM), ion mobility spectrometry (IMS) and FISH technique, i.e. fluorescence *in situ* hybridization (Mańczuk, 2014) are used to work on hair. In the context of this article, special attention should be paid to scanning microscopy, which provides tools for accurate morphological analysis of hair, as well as for identifying changes in its structure chemical composition.

Aim and hypothesis of the study

The aim of the study was to determine whether identification of dog and cat genera was possible basing on morphological features selected by the Authors. Consequently, the following working hypothesis was adopted: morphological analyses of length, shape, colour, life cycle phase, shape of medulla and hair ends of dog (*Canis lupus familiaris*) and cat (*Felis catus*) allow generic identification.

Animal hair in identification procedure

Animal hair is a biological forensic trace. A review of the literature shows that animal identification most often begins from morphological features. There are few sources treating on detailed analysis of dog and cat hair, which may be due to the fact that precise species identification based on hair often requires an appointment of zoology experts (Moore, 1998). According to literature of the subject, the basic assumption for the generic identification of animals (based on morphological studies of the hair) is the fact that individual mammal species (e.g. cat, dog or fox) differ in hair pigmentation, thickness of medulla or hair cuticle pattern (Venkatesan, 2006). The discrimination power of evidence basing on human or animal hair morphology analysis is low, therefore only consistence

in several features can be sufficient evidence for a truly accurate determination of genetic affiliation (Bhat et al., 2014).

Basing on the works of Polish authors it can be shown that animal and human hairs are creations of epidermis and, just like claws and nails, are among the biological traces most often found at incident scenes. What is important in forensic context, Włodarczyk (2007) reports that epidermal products, especially animal and human hairs, are characterised by particular resistance to the effects of destructive environmental factors, including the impact of microbiological fauna. Lightness and a large amount of hair make it virtually impossible to completely remove it from the place where the animal was present. On the other hand, light weight facilitates carrying along with the wind, which significantly hampers connecting the suspect to the victim or the exact location of committing the crime (Włodarczyk, 2007). Comparisons of hair are useful in attempts to identify an animal, e.g. in cases related to their smuggling or poaching (Dębska, 2013). Literary sources also report on the usefulness of forensic analyses of animal hair aiming at establishing the identity of a person identity, or objects that are likely implements of committing a crime (Kędzierska, Kędzierski, 2011).

Finding any kind of epidermis creations ought to induce steps aiming at maintaining the traces in the best possible condition and diagnostic value particularly in the present times, that is the era of rapid progress with an increasing pressure on *wildlife forensics* (Dębska, 2013). The situations of breaching the law referring to protection of wild life often occur in remote and sparsely populated locations (Brunner, Coman, 1974). In order to recover a given trace animal or human hairs should be inserted in special packaging made of paper (that is supposed to protect them from moisture that might lower the evidential value; Miller-Coyle, 2008).

Animal hair as forensic trace

The widespread presence of pet hair (such as a dog or cat's) is obvious. It is no different with the presence of hairs at crime scenes (Verma, Joshi, 2012). The difference between animal hair and human hair, although they show some similarities, is observable (Priyanka et al., 2017). Demonstration of consistent features of animal hairs recovered from a suspect (or collected at a scene of crime) and those disclosed in the context of collecting comparative material may indicate their contact or provide valuable information about one of the parties of the proceedings: whether a given person has an animal and what animal it is. Human and animal hair identification can also be helpful in the following parts of the process of detection and investigation:

– leading to the scene of crime,
– linking the scene with the suspect or victim,
– determining the course of incident.

Hair transfer can take place in the following directions: from person to person, from person to crime scene or from crime scene to person. In the first two cases, the perpetrator or victim may be the owner of the animal – the transfer of biological traces is then two-directional (Verma, Joshi, 2012). Hair transfer in the third direction usually occurs when the crime was committed in the place where the animal was kept. Boehme enlists rooms and buildings such as basements, pens, barns and stables (Boehme et al., 2009). Animal hair analysis for the purposes of judicial proceedings is a scientific method of examining crime scene forensic evidence. According to the laboratory good practice hair examination should begin with an attempt to determine whether it is of human or animal origin (Verma, Joshi, 2012). Once it is classified as animal hair, one should endeavour to define its generic affiliation, and with use of extensive knowledge of the subject matter and equipment of high resolution class: also the species (Bisbing, 2001).

The difficulty lies in the fact that animals produce different hair in different parts of their body. For example, most animals have much longer hair in tails and manes than on the trunk. Due to the diversity of the *canine* species into numerous breeds (currently around 400 are distinguished) significant differences in the appearance of their hair can be observed within each specie. A rich source of information in this area is the article by Wandhare and Bhosale, in which the Authors report analysis of a collection of hair taken from the central part of the back from dogs of fifteen breeds (Wandhare, Bhosale, 2017). An examiner working with a hair sample ought to begin with determining the degree of variation within the sample and comparing whether the tested hair falls within the specified range (Deedrick, Koch, 2004). Due to the shortage of experts trained in morphological analysis of animal hair, this type of identification may be inconclusive as regards species identification and in such cases only DNA analysis most often grants confidence (Pilli, 2012). Forensic analysis of hair focuses on morphological observation made under magnification using an optical microscope connected to an external computer via an image recording tool (e.g. a camera). In the structure of a hair itself (regardless of its origin), three layers are important from the point of view of methodology: cuticle, cortex and medulla (Zafarina, Panneerchelvam, 2009).

Work on identification of animal hair is easier when the analysed traces demonstrate features typical for a given genus of animal (Barksdale, Humrich, 2017), and in addition to that, they are affected by a disease or contaminants. During the examination, having this type of forensic exhibit to one's disposal one should use protective measures, including working in an apron, mask and a protective cap on your hair. It is also important not to talk above the samples. One should also prevent drafts in the work room or other situations

generating a gust of air, because due to the exhibit's its lightness it is very easy to lose it.

Selected morphological features of animal hair

The pattern of scales covering the cuticle, the type and diameter of the medulla and the colour (Yasser et al., 2018) are of substantial importance for identifying animal hair. Examination by comparing these features allows not only to distinguish between hair of different animals, but also to indicate whether a given exhibit originates from an animal (animal hair) or from a human (human hair). An article by Italian researchers working under supervision of Alessia Mariacher published in 2019 presents the methodology of hair identification aimed at complying with EU law prohibiting trade in dog and cat fur (Mariacher et al., 2019). At least one analytical method can be applied for identification, including the morphological analysis of animal hair discussed in this article. In addition to that, DNA analysis and MALDI-TOF mass spectrometry can be used for these purposes (Mariacher et al., 2019). According to the team of Italian researchers, identifying species whose fur selling is banned is not easy, since many animals aimed for fur industry exhibit significant phenotypic similarities to those being subject to restrictions.

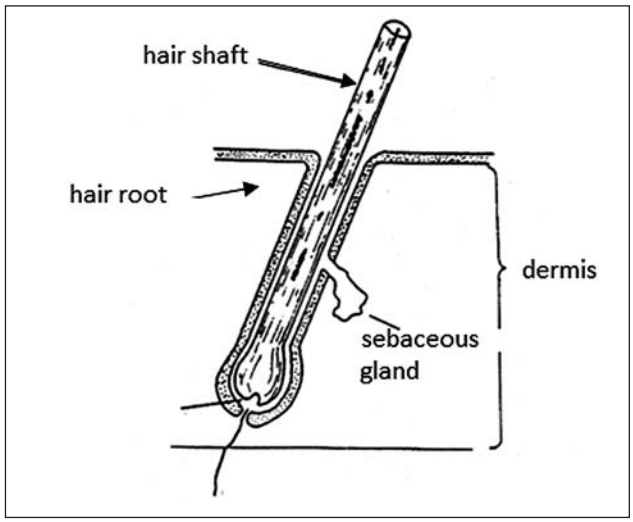

Fig. 1. Animal hair shaft and root.

A hair consists of a shaft and a root. The shaft, often also called a stem, is the part of the hair that protrudes above the surface of the dermis and epidermis. It may have many different shapes. Its cross section, however, it usually the one of a cylinder. Below the surface of the skin there is the hair root, commonly called a bulb (Yasser et al., 2018).

In the structure of the hair shaft, the following components can be distinguished: sheath (cuticle), cortex and medulla. Of these, the cuticle and the medulla have the greatest diagnostic significance in the context of forensic examinations (Knecht, 2012). Figures 2 and 3 show the longitudinal section and cross-section of a hair shaft.

In a hair it is the cuticle that contains the largest amount of keratin that contributes to its mechanical durability. This component is the outermost layer of hair structure and may have a variety of patterns that play a very important role during identification (Gharu, Trivedi 2015). Patterns of scales on animal hair, which are schematically classified and shown in Figure 3, change depending on hair length (Gharu, Trivedi 2015).

The medulla is another important element of hair morphology. According to scientific reports in most animals the medulla is continuous and wide in relation to the total diameter of the shaft. This structure is the innermost layer of a hair. For identification and comparison purposes, not only the appearance of the medulla, but also its diameter is meaningful (Wandhare, Bhosale, 2017).

The hair life cycle can be divided into the following phases: anagen, catagen and telogen. In each of these phases, the hair root (so-called hair bulb) looks different (Gharu, Trivedi, 2015). Knowledge of these differences allows to determine, among others, whether a hair has fallen off or been pulled out. Figure 5 shows the hair roots at every stage of hair life cycle. The presence of hair in the anagen and catagen phases indicates that they have been pulled out by force, because they naturally fall off only in the telogen phase (Brunner, Coman, 1974).

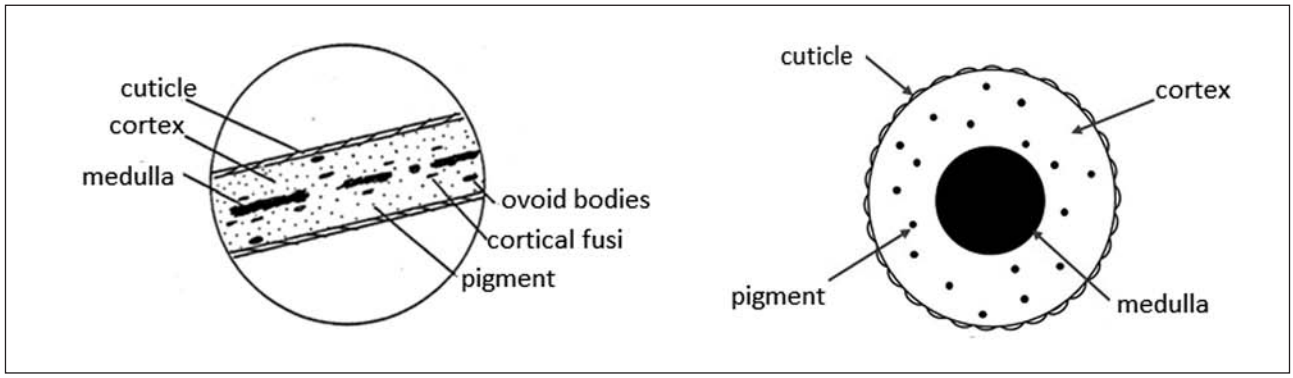

Fig. 2. Longitudinal section and cross-section of hair shaft.

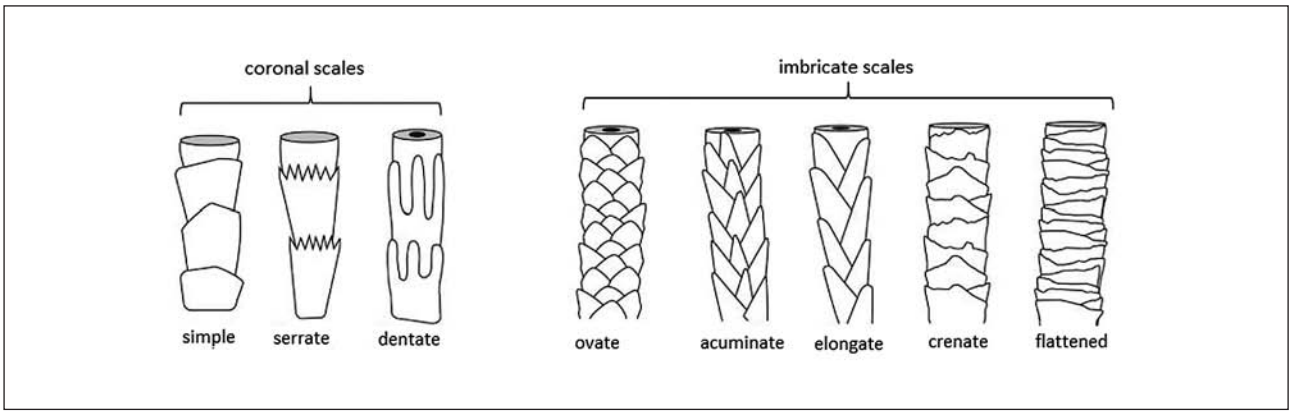

Fig. 3. Types and possible patterns of cuticle.

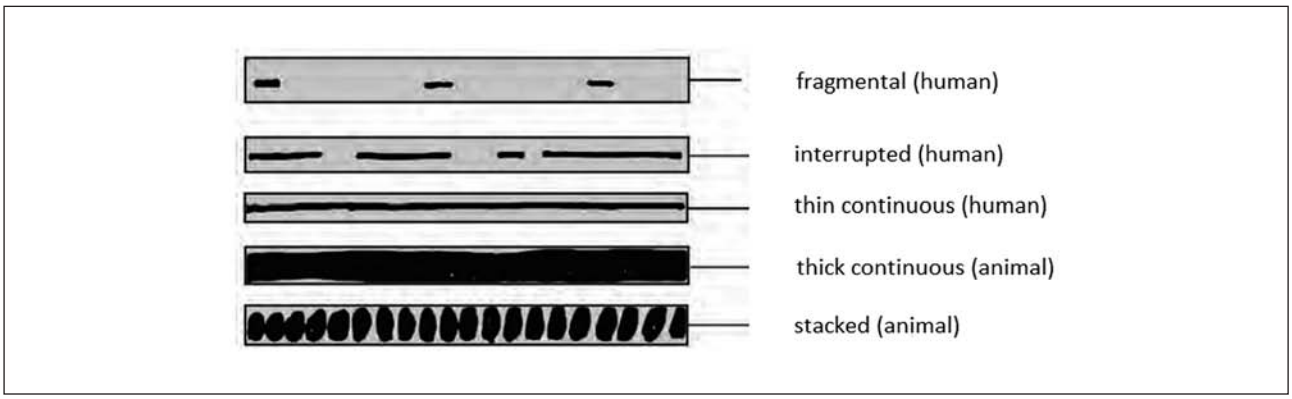

Fig. 4. Range of features of animal hair medulla and their occurrence.

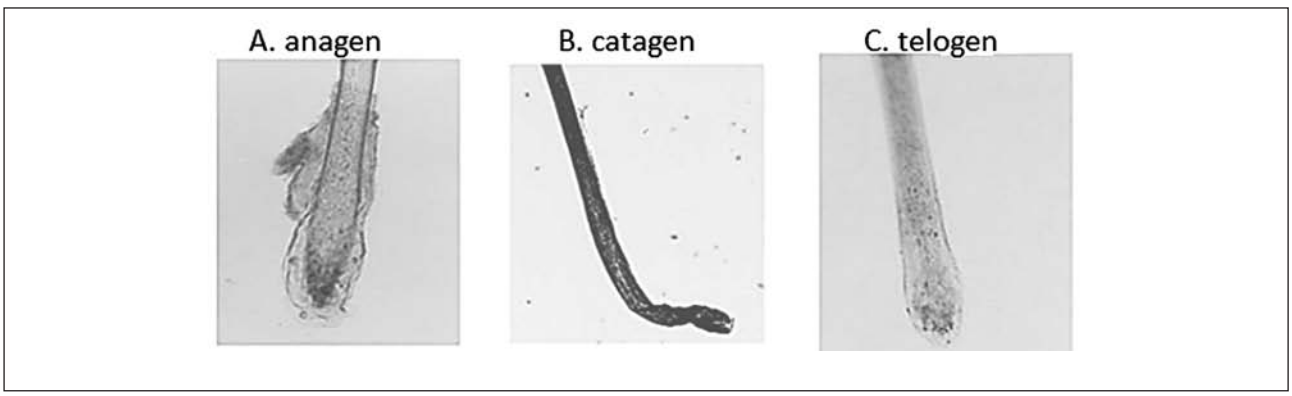

Fig. 5. Appearance of animal hair roots in specific phases of life cycle.

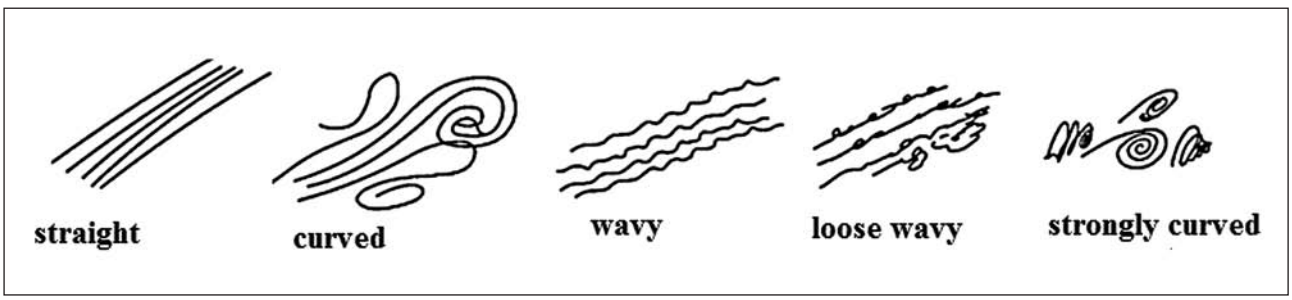

Fig. 6. Examples of hair shapes.

Table 1. Selected features of animal hair morphology and their exemplary range.

No.	Feature	Feature range
1.	**Trace origin**	human hair animal hair (hair coat)
2.	**Hair shaft**	straight pointed oblate
3.	**colour/ pigmentation**	no colour (grey) brown black
4.	**medulla**	continuous interrupted fragmental absent obscured stacked
5.	**Life cycle phase**	anagen catagen telogen
6.	**End shape (root)**	pointed cone square cut off rounded broken
7.	**shape**	straight curved wavy loose-wavy strongly curled

The last morphological feature of animal hair selected for the needs of methodology of the practical part of the article is hair end shape.

Characteristic features of dog and cat hair

The hair coat is a permanent element of animal morphology. It ensures normal functioning in the environment and facilitates adaptation to changing conditions in the ecosystem (Nabożny, 2015). The hair coat is involved in processes of thermoregulation, protects against environmental factors (e.g. UV radiation) and plays a defensive function, for example by bristling (Kondo et al., 2004). In the species identification the hair that has defensive functions is the most important (Knecht, 2012; Tridico, 2005).

According to the work of Kshirsagar et al. the diameter of the hair shaft in dogs equals 25 μm, while in cats this value is approximately 30 μm (Kshirsagar et al., 2009). These Authors ventured to set a quantitative parameter that would be most useful for distinguishing between human and animal hair. Their studies also indicate that for the selected animal species the medulla index varied from 0.44 to 0.70. Another study carried out by an Italian team of scientists led by Dr. Venusia Cortellini presents a variety of human hair and hair of six animal species, including dog (*Canis lupus famis*) and cat (*Felis catus*). In the light of these studies, it ought to be taken into account that dog's hair root usually has a mace-like shape, while in cat it narrows towards the end in the shape of a cone (Cortellini et al., 2019).

The diameter of the medulla in dog hair is usually 1/2, while the medulla in cat hair is thicker (over 1/2 the width)

Fig. 7. Shapes of hair root ends: a – dog, b – cat.

Fig. 8. Medulla appearance a – dog, b – cat.

(Yasser et al., 2018). Additionally, the medulla in dog hair is often invisible (amorphous), unlike in cat hair where it is clearly noticeable. What is more, the medulla in dog hair is continuous and has a form of layers (Cortellini et al., 2019; Houck, Budowle, 2002). It should be noted that there may be discrepancies between various Authors' descriptions of the dog medulla. The medulla in dog hair observed by the Authors of this article during the morphological analyses corresponded with the description presented in the publication: Yasser et al., 2018, while it differed from the description contained in: Mukherjee et al., 2016; the latter authors report that in this respect the medulla in dog hair was discontinuous or, as they refer to it, "vacuolated" (Mukherjee et al., 2016).

The cuticle of *Canis lupus familiaris* hair may be indistinct, but if one succeeds in observing it, among the special features it is worth emphasising the presence of imbricate type scales. The term should be interpreted in this context as pavement-like scales, flattened and composed of overlapping elements with narrow margins (Deedrick, Koch, 2004). In domestic cats hair, the scales shape tends to be pointed (Cortellini et al., 2019).

Materials and methods

The study material was selected after analysing 3986 samples of human and animal hair recovered in the course of an archival investigation of a murder with particular cruelty of a student whose corpse was revealed in the territory of Cracow. 270 animal hair samples were selected for further testing. The analyses were performed on material in form of recovered traces, selected by extended morphological diagnostics, i.e. with inclusion of type of scales in addition to the features used for the purposes of this work.

During the examination the hair placed in paper packets was removed with tweezers and placed on a contrasting background (black for light hairs and white for dark ones) and photographed with a 30 cm ruler. At the same time, each exhibit's length was measured in centimetres. After recording by photography and measuring, the material was analysed in terms of shape. Then it was placed on a degreased microscope slide and a cover slip was applied, after which the sample was placed under a Delta Optical microscope, model Evolution 300, and observed under a 10-20 and 40x magnification lens. The view from the lens, via microQUCMOS03100KPA camera, was transmitted to a computer program enabling a detailed analysis of selected morphological features of the hair (i.e. its colour, life cycle phase, the medulla and end shapes). Information about each slide was entered into a specially prepared Microsoft Excel 2007 spreadsheet. After filling in the form, the slide was removed from under the lens, and the hair from it was replaced in the paper package with tweezers.

Analytical results

In order to compare the lengths of dog and cat hair a comparative analysis by means of Mann–Whitney U test was performed. The result of that analysis with the descriptive statistics is presented in the Table below.

The result of analysis by the Mann–Whitney U test proved to be statistically significant: $Z = 2.08$; $p < 0.05$; $r = 0.13$. It was shown that dog's hair was longer than cat's ($M = 3.28$; $SD = 1.62$ vs $M = 2.93$; $SD = 1.28$). However, these differences were not very strong.

The subsequent analyses involved comparing of animal hair parameters, its colour, medulla, roots (bulbs)

Table 2. Descriptive statistics of hair lengths of dog and cat, as well as the result of Mann–Whitney U test comparative analysis.

		M	*SD*	*Me*	*Z*	*p*	*r*
Hair length	Dog	3.28	1.62	3	2.08	0.038	0.13
	Cat	2.93	1.28	2.5			

M – mean, ***SD*** – standard deviation, ***Me*** – median, ***Z*** – Mann–Whitney U statistics, ***p*** – statistical significance level, ***r*** – significance of differences

Table 3. Results of analyses with Chi-square tests of independence for the relationship of shape, colour, medulla, bulbs and ends of hairs between dog and cat.

	χ^2	*df*	*p*	*V*
Shape	3.56	3	0.313	0.12
Colour	16.06	10	0.098	0.24
Medulla	5.45	3	0.142	0.14
Bulbs	4.56	2	0.102	0.13
Ends	8.99	4	0.061	0.18

χ^2 – Chi-square statistics, ***df*** – number of degrees of freedom, ***p*** – level of statistical significance, ***V*** – Cramer's V strength of association

and ends between samples from dogs and cats. For that purpose, a series of analyses with Chi-square test of independence were conducted and their result are presented in Table 3.

The results of the analyses turned out to be statistically insignificant: $p > 0.05$, which means that there were no differences between the cat and the dog in terms of: hair shape: $\chi2$ (3) = 3.56; p = 0.313; V = 0.12, colour: $\chi2$ (10) = 16.06; p = 0.098; V = 0.24, medulla appearance: $\chi2$ (3) = 5.45; p = 0.142; V = 0.14, bulbs: $\chi2$ (2) = 4.56; p = 0.102; V = 0.13 and ends: $\chi2$ (4) = 8.99; p = 0.061; V = 0.18. In both dogs and cats most often the hairs were curved or loosely wavy, the ones of grey-brown or brown color predominated, the medulla was continuous, the root was in the telogen phase, and the ends were frayed or in the form of a pointed cone.

Next, the relationship between individual dog and cat hair features was examined. For the elationship between hair features and their length, a series of analyses were performed using Kruskal–Wallis tests, the results of which are presented in Table 4.

The results of the analysis by Kruskal–Wallis tests showed that the length of hair was associated with its type in both dogs: $\chi2$ (3) = 8.15; $p < 0.05$ and cats: $\chi2$ (3) = 12.66; $p < 0.01$. It was observed that in the dog hair was the longest in the case of wavy hair and in cats the case of loose wavy hair, while the shortest was straight hair, regardless of the animal. It was not demonstrated that the length of cat and dog hair

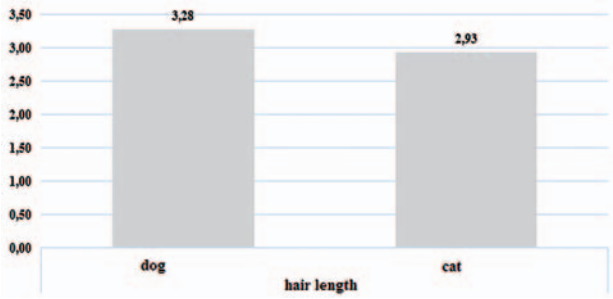

Fig. 9. Dog and cat hair length – mean values (in centimetres).

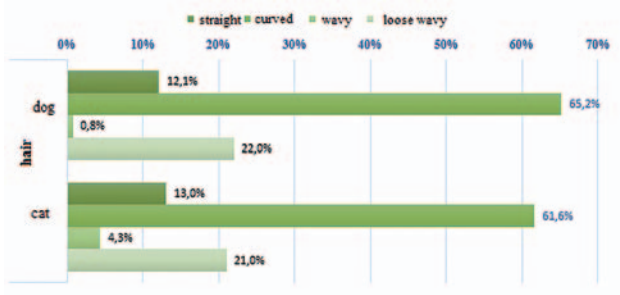

Fig. 10. Distribution of dog and cat hair shapes.

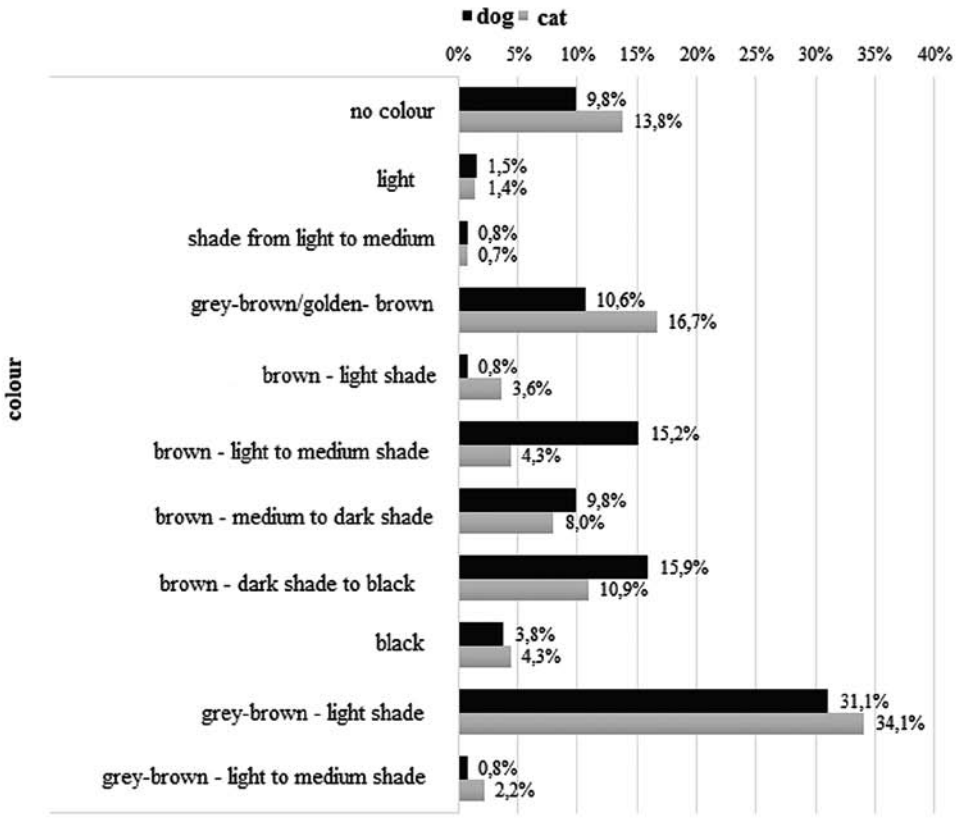

Fig. 11. Distribution of dog and cat hair colours.

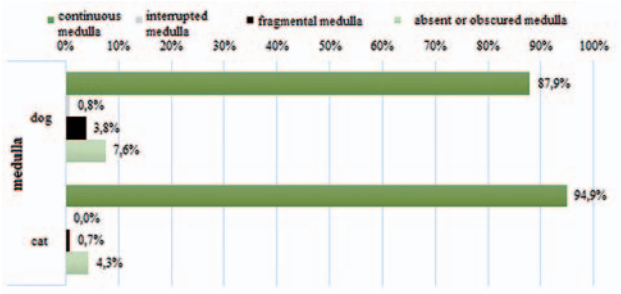

Fig. 12. Distribution of dog and cat hair medulla.

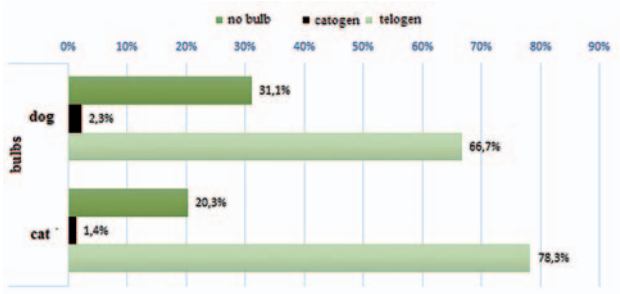

Fig. 13. Distribution of dog and cat hair bulbs.

Table 4. Descriptive statistics for the length of the dog and cat hair broken up into the shape of the hairs and the result of comparative analyses by the Kruskal–Wallis tests.

		Dog			χ^2	*df*	*p*	Cat			$\chi2$	*df*	*p*
		M	***SD***	***Me***				***M***	***SD***	***Me***			
Hair, shape	Straught	2.47	0.67	2.5	**8.15**	**3**	**0.043**	2.17	0.69	2	**12.66**	**3**	**0.005**
	Curved	3.43	1.73	3				2.88	1.03	3			
	Wavy	5.00	0.00	5				3.25	1.57	2.5			
	Loose wavy	3.22	1.56	3				3.50	1.83	3			
Colour	No colour	3.96	1.70	3.5	15.44	10	0.117	2.87	0.72	2.5	10.02	10	0.438
	Light	6.50	0.71	6.5				3.50	2.12	3.5			
	Shade from light to medium	1.00	0.00	1				5.50	0.00	5.5			
	Grey-brown/golden brown	3.96	2.94	3				3.41	2.04	3			
	Brown – light shade	4.00	0.00	4				3.60	1.71	3			
	Brown – light to medium shade	2.93	1.05	3				2.83	0.75	3			
	Brown – medium to dark shade	3.17	1.80	3				2.59	1.24	2.5			
	Brown – dark to black shade	2.79	0.96	2.5				2.73	1.00	2.5			
	Black	3.50	0.94	3.5				2.25	0.52	2.25			
	Grey-brown – light shade	3.15	1.30	3				2.82	1.07	2.5			
	Grey-brown – light to medium shade	3.50	0.00	3.5				2.83	0.29	3			
Medulla	Continuous medulla	3.25	1.61	3	3.03	3	0.387	2.93	1.29	2.5	3.25	2	0.197
	Interrupted medulla	4.50	0.00	4.5									
	Fragmental medulla	4.50	2.45	3.5				5.50	0.00	5.5			
	Absent or obscured medulla	2.95	1.21	3.25				2.50	0.55	2.5			
Bulbs	No bulb	3.29	1.68	3	0.16	2	0.922	3.39	1.93	3	0.95	2	0.623
	Catagen	2.83	0.58	2.5				2.50	0.71	2.5			
	Telogen	3.30	1.62	3				2.82	1.04	2.5			
Ends	End in form of pointed cone	3.25	1.59	3	1.00	4	0.909	2.88	1.36	2.5	4.26	4	0.372
	Square, cut, rouded end	2.94	1.10	3				3.12	1.52	2.5			
	Slantin, cut, rouded end	2.94	1.29	2.5				3.90	1.39	4			
	Frayed end	3.42	1.78	3				2.86	1.20	3			
	Broken end	3.60	1.95	2.5				3.50	0.00	3.5			

M – mean, ***SD*** – standard deviation, ***Me*** – median, χ^2 – Kruskal–Wallis statistics, ***df*** – numer of degrees of freedom, ***p*** – level of statistical significance

Table 5. Results of analyses by Chi-square tests of independence for dog and cat hair features.

			χ^2	*df*	*p*	*V*
Shape	Colour	Dog	22.95	30	0.817	0.24
		Cat	42.32	30	0.067	0.32
	Medulla	Dog	4.63	9	0.865	0.11
		Cat	**24.21**	**6**	**0.000**	**0.30**
	Bulbs	Dog	9.10	6	0.168	0.19
		Cat	**13.36**	**6**	**0.038**	**0.22**
	Ends	Dog	14.93	12	0.245	0.19
		Cat	**23.85**	**12**	**0.021**	**0.24**
Colour	Medulla	Dog	**72.95**	**30**	**0.000**	**0.43**
		Cat	**46.86**	**20**	**0.001**	**0.41**
	Bulbs	Dog	**45.11**	**20**	**0.001**	**0.41**
		Cat	**33.45**	**20**	**0.030**	**0.35**
	Ends	Dog	51.61	40	0.103	0.31
		Cat	**92.26**	**40**	**0.000**	**0.41**
Medulla	Bulbs	Dog	5.69	6	0.459	0.15
		Cat	4.09	4	0.393	0.12
	Ends	Dog	11.72	12	0.469	0.17
		Cat	14.82	8	0.063	0.23
Bulbs	Ends	Dog	**22.74**	**8**	**0.004**	**0.29**
		Cat	**31.91**	**8**	**0.000**	**0.34**

χ^2 – Chi-square statistics, ***df*** – number of degrees of freedom, ***p*** – level of statistical significance, ***V*** – Cramer's V strength of association

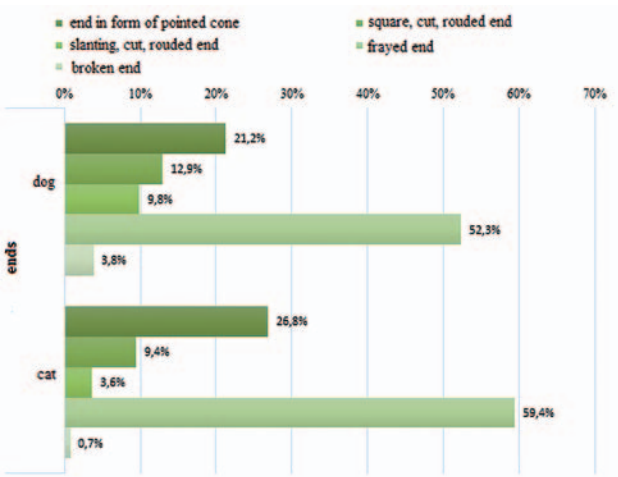

Fig. 14. Distribution of dog and cat hair end shapes.

Fig. 15. Mean values of dog and cat hair lengths (in centimetres) divided according to shapes.

was related to its colour, medulla, root on end shape (statistically insignificant results: p> 0.05).

Then, a series of analyses using the Chi-square tests of independence were again used for the relations between the individual hair characteristics of the cat and dog. The results of all analyses are presented in Table 5 above, and due to the multitude of results, **only statistically significant ones have been described.**

The results of the Chi-square tests of independence showed that in the case of a cat there was a statistically significant relationship between the shape of the hair and its medulla: $\chi2$ (6) = 24.21; p <0.001; V = 0.30, bulbs $\chi2$ (6) = 13.36; p <0.05; V = 0.22 and with ends: $\chi2$ (12) = 23.85; p <0.01; V = 0.24. Wavy hair definitely had a fragmentary medulla, no bulb, the end of the hair was oblique or square. Among the remaining fur shapes continuous medullas and bulbs in the telogen phase predominated, and the ends were frayed.

It was also demonstrated that colour of dog and cat's hair was associated with medullas, bulbs and hair ends. A medulla other than continuous was most often found in black and dark brown hair. Lack of bulbs was observed most often in brown and grey-brown hair. The grey-brown hair most often had frayed tips, whereas the brown hair: square and oblique.

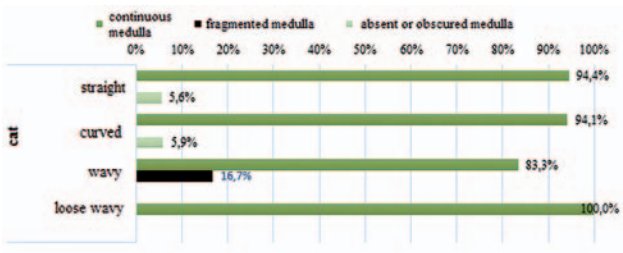

Fig. 16. Relationship between shape of hair and its medulla in a cat.

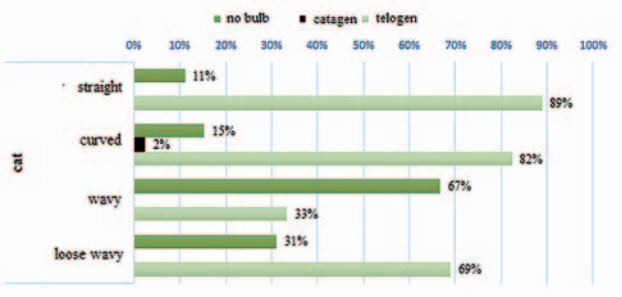

Fig. 17. Relationship between shape of hair and bulbs in a cat.

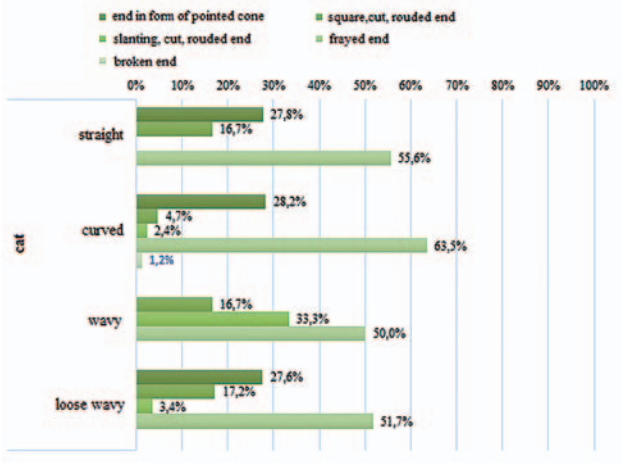

Fig. 18. Relationship between shape of hair and its end in a cat.

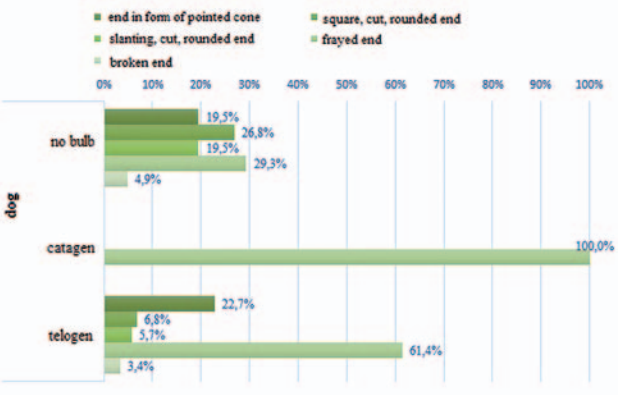

Fig. 19. Association between dog hair bulbs and ends.

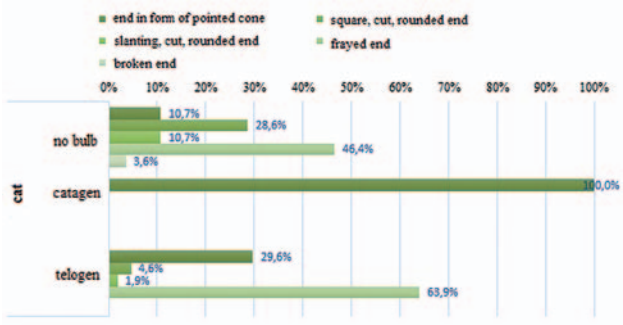

Fig. 20. Association between cat hair bulbs and ends.

It was also proven that the type of bulbs was associated with the type of hair ends in both dogs: $\chi2$ (8) = 22.74; $p < 0.01$; V = 0.24 and cats: $\chi2$ (8) = 31.91; $p < 0.001$; V = 0.34. In bulbs in the catagen phase there were only frayed tips and in the form of a pointed cone, in the case of telogen the ends in the form of a pointed cone dominated, while oblique and square tips predominated in hair without bulbs.

Summary

Morphological analyses of length, shape, colour and life cycle phase, shape of medulla and hair ends of dogs and cats do not enable full species identification. However, in case of cat's hair stronger associations of individual morphological variables were demonstrated. Basing on information presented in the theoretical part and methodology adopted for the needs of executing the practical part it should be concluded that morphological analysis of hair ought to be extended with identification of cuticle scales pattern. Comparison of dog and cat hair in the light of morphological features may be insufficient for differentiation between the species. Rejection of the hypothesis, understood as the fact that the morphological analyses of selected animal hair features are not sufficient for species identification, stresses the usefulness of DNA identification. Due to that such methods may be useful as a an element of selecting material evidence.

Sources of Figures and Tables

Figures 1–2: Deedrick, Koch, 2004; Yasser et al., 2018
Figure 3: De Marinis, Asprea, 2006; Zafarina, Panneerchelvam, 2009
Figure 4: Authors, basing on: De Marinis, Asprea, 2006
Figure 5: Authors, basing on: Erdoğan, 2017
Figure 6: Seta at al., 1988
Figures 7–8: Cortellini at al., 2019
Figures 9–20: Authors
Tables 1–5: Authors

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