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Hair Diameter Distribution in Sheep Interspecies Hybrids[1]

E. B. Vsevolodov[a], G. J. Sarsekeeva[a], I. F. Latypov[a], L. Aliev[b], V. A. Golichenkov, A. S. Musaeva[a], and R. Zhapbasov[a]

[a] Institute of General Genetics and Cytology MES RK

[b] Shymkent Zoo

e-mail: eduardvsevolodov@mail.ru

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Abstract—Hair diameter distribution was studied in wild sheep species (argali—*Ovis ammon*, mouflon—*O. Musimon*; domestic sheep—*O. aries*) and their hybrids. In wild species and their hybrids, rather distinctly separated subpopulations of thin (underwool) hairs (10–22 μm diameter) and thick (kemp) hairs (85–302 μm) were detected, and intermediate diameters were rare. In domestic sheep, the kemp subpopulation was very poor, not distinctly separated from the underwool, while maximal hair diameter was <150 μm. In wild × domestic crosses, the kemp subpopulation was clearly expressed, shifted to lower diameter range, and maximal diameters was <200 μm. The same restriction was found in two-month-old wild species lambs compared with adults.

Keywords: *Ovis ammon, O. musimon, O. aries*, wild and domestic sheep, underwool, kemp, hairs.

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Wild sheep hair is known as consisting of clearly differentiated kemp and underwool, and a low number of intermediate hairs are met also. The diameters of the thickest kemp may exceed 300 μm (approximately 1/3 mm) and the thinnest were lower than 10 μm (1/100 mm), which is the single blood cell—lymphocyte dimension [1–3]. Sheep domestication was accompanied by historical selection for the relative decrease in the range of the hair diameter variability.

Obtainment of wild × domestic sheep hybrids may help to elucidate the character of interaction of domestic and wild species genomes in the course of hair cover formation in such hybrids.

In Shymkent Zoo, some interspecies hybrids of wild sheep of different generations were crossed with domestic sheep that allowed us to investigate peculiar characters of their hybrid hair cover in comparison with parental species.

Two different approaches to the nature of the difference between kemp and underwool are theoretically possible:

(1) The difference between them firmly persists because self-supporting expression of different gene sets takes place in kemp and underwool hair follicles; that is, different epigenetic heredity arises in the subpopulations of originally common epidermis cells' population that produces both hair subpopulations [4].

(2) No epigenetically supported difference exists between kemp and underwool, but the distinction arises only because of developed dissimilar self-supporting physiological conditions; for example, different dimensions of formed dermal papillas of the hair follicle bulbs.

This assumption can be confirmed in part by microsurgical experiments of the British researcher Oliver [5] who showed that dermal papillas of different dimensions induced in epidermis hair follicles of different dimensions.

MATERIALS AND METHODS

Three species of sheep were used: wild—mouflon (Ovis orientalis) and argali (O. ammon)—and domestic sheep (O. aries), kept in Shymkent Zoo for several recent years. Also, carpet domestic sheep and interspecies hybrids mouflon × argali of different generations and complex hybrids [(mouflon × argali) × domestic sheep] were investigated. Hairs were clipped from the midlateral part of the body near the scapula from grown up animals in April (before the moulting) and from two-month lambs (June), whose hair cover still kept an immature (juvenile) character.

Approximately one millimeter length segments were cut off and discarded from the undisturbed hair clusters using a fresh blade to level the hairs; then, using another fresh blade, the next as short as possible segments of the hair clusters were cut off. These latter segments (after they were separated from their clusters) consisted of short (less than 1 mm) segments of particular hairs (one segment only from any particular hair).

[1] The article was translated by the authors.

Differences of hair thickness distribution in wild, domestic sheep, and their hybrids (hair samples clipped from grown up animals in April before moulting)

Genotype	Hair number mean proportion (%) and range of proportions in different animals							
	10–14 µm	10–19.9 µm	20–22.3 µm	20–44.6 µm	44.7–99 µm	100–199 µm	200–315 µm	>45 µm
Mouflon*	41 ± 1.2	54 ± 1.6	3 ± 0.5	8 ± 0.9	11 ± 1.0	27 ± 1.4	0.2 ± 0.14	38 ± 1.5
Argalis (spring)	42 ± 5.5 (38–47)	54 ± 4.8 (48–59)	3.6 ± 3.4 (0.2–7)	3.6 ± 3.4 (0.2–7)	0.35 ± 0.35 (0–0.7)	26 ± 24 (3–48)	14 ± 12 (2–25)	40 ± 12 (28–51)
Domestic Sheep** (spring)	*8* ± 0.7 (*7–8*)	*24* ± 3.5 (*20–27*)	**40** ± 0.7 (**39–40**)**	**64** ± 3 (**61–67**)	7 ± 1 (6–8)	2.6 ± 2.4 (0.1–5)	0	*9* ± 3 (*6–12*)
Hybrids argali × mouflon	16 ± 3.0 (13–19)	39 ± 2 (37–41)	15 ± 9 (6–24)	16 ± 9 (6–25)	1 ± 1 (0–2)	24 ± 16 (7–40)	21 ± 2.4 (15–27)	46 ± 14 (34–57)
Hybrids with domestic sheep blood	36 ± 15 (20–51)	49 ± 12 (37–61)	10 ± 10 (0.3–21)	12 ± 11 (0.4–23)	18 ± 14 (4–33)	19 ± 16 (2.7–35)	0	38 ± 1.6 (36–39)

Notes: * Statistical errors (SE) for the only mouflon corresponds to confidential intervals for comparing different columns of the same line and the other SE to compare different lines of the same columns.

** Large differences are stressed in the hair diameter distribution in domestic even carpet breed and wild sheep and their hybrids. Bold–face—increased proportion of hairs within diameter range 20–45 µm; italics—low proportion of hairs with extreme diameters <20 and >45 µm

These hair segments were transferred onto a slide with some glycerol poured on it, dispersed over it, and covered by a large cover glass. The preparation was set under a lanometer projection microscope produced by the Reichert firm. Data of hair diameter measurements were distributed to diameter classes using our original computer program "rzbclg30.bas"; logarithm of mean diameters of classes were set along the abscissa axis and the rate (%) of all hair measured falling into every class were set along the ordinate axis. Mean diameters in the adjacent classes differed by constant factor 1.12.

Data on distribution of hairs among the diameters classes obtained for every animal were presented as tables. The Excel program was used to make the corresponding graphs.

Microphotos were made using a digital photocamera on a Micros (Austria) microscope with objective 40× and magnification on the display 500×.

RESULTS AND DISCUSSION

In Fig. 1, a kemp, an intermediate hair, and two underwool hairs of wild sheep species are presented at the same magnification. Strongly developed reticulate medulla is present in the kemp, while the cortex layer contributes little to the hair diameter at its periphery. The transitional hair is much thinner and also includes well-developed medulla; its reticulate structure is not expressed perhaps because of strong pigmentation. Medulla is fully absent in the underwool hairs here presented and the borders of the outer hair layer cuticle scales are easily discerned.

Hair diameter distribution of grown up sheep of different genotypes clipped in April two months before the moulting is shown in Fig. 2. It can be seen that two peaks of distribution curves corresponding to kemp and underwool are present in mouflon, argali, and their hybrids (abscissae of the underwool peaks were

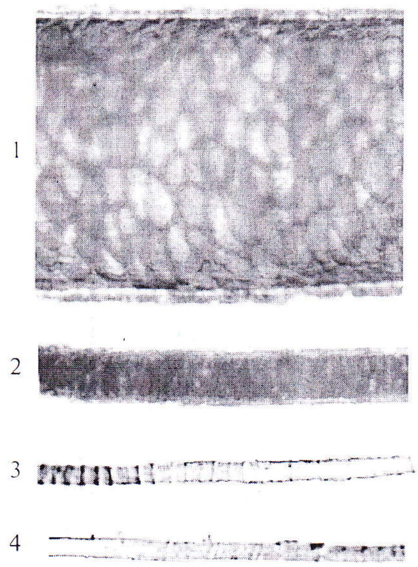

Fig. 1. General view of different hair types of wild sheep. 1—Grown up argali kemp (hair diameter 205 µm); 2—transitional hair (35 µm) of grown up mouflon; 3—underwool hair (13.8 µm) of mouflon; 4—underwool hair (10 µm) of argali.

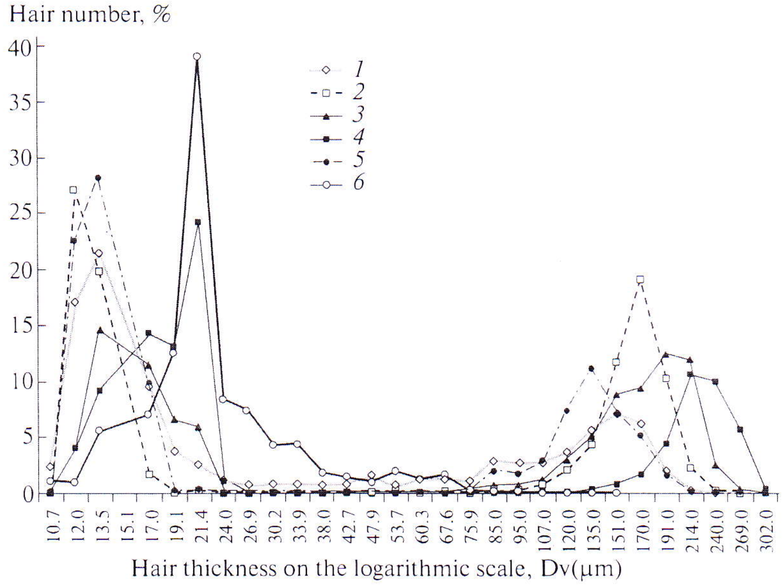

Fig. 2. Distribution of hairs among the classes of diameters in grown up interspecies sheep hybrids and their original parental species (argali, mouflon, domestic sheep). Abscissae axis—hair thickness in μm on a logarithmic scale. Ordinate axis—proportion of the hairs fallen to every thickness class (%). *1*—mouflon; *2*—argali; *3*—F1-hybrid of the first generation of crossing mouflon and argali; *4*—another analogous hybrid; *5*—complex interspecies hybrid obtained by crossing F2 mouflon × argali hybrid with domestic sheep; *6*—domestic sheep. Explanation along abscissae axis just on Fig. 2.

13.5, 12, 13.5, 21.4 μm; peaks of the kemp were 151, 170, 191, 214 μm). The domestic sheep hair diameter distribution curve clearly displays only one peak corresponding to underwool hairs (21 μm). In complex three species hybrid with the domestic sheep blood admixture, underwool hairs' peak abscissa is 13.5 μm and kemp peak absciss is 135 μm as in more simple hybrids.

Maximum of the distribution curve in argali for underwool falls into the class with the lowest mean hair diameter. Hairs within the diameter range 19–95 μm are hardly present and the peak corresponding to kemp is definitely separated from that of underwool. In single mouflon studied, the peaks for kemp and underwool are displaced compared with those of argali to the right from argali "underwool peak" and to the left from "kemp peak." Underwool and kemp peaks in mouflon are not isolated as fully as in argali but are connected by an almost continuous chain of intermediate diameter classes, though every such class contains only few hairs.

In domestic sheep, the proportion of hairs in the first (thinnest) three classes of diameter is very low. Surprisingly, many hairs are concentrated in the single class 20–22.3 μm (table). In the next classes up to the class 35.5–39.8 μm, the proportion of hairs in domestic sheep stays higher than in any other presented in Fig. 2. The hairs with the diameter higher than 76 μm were practically absent: only one hair out of 1000 measured fell into class 126–141 μm.

Thus, hair cover of the mouflon closely resembling that of argali differs from it by slight displacement towards the domestic one.

The hybrids of mouflon and argali differ from argali by displacement of their hair diameter distribution peaks presenting both kemp and underwool to the right towards higher diameters.

It cannot be excluded that we have here an example of heterosis effect caused by the interspecies crossing of far genotypes. In these hybrids, distinct separation of underwool and kemp peaks is detected; the intermedial diameters from 24–27 to 76–135 are absent.

In complex hybrid with 1/4 mouflon genotype, 1/4 argali, and 1/2 domestic genotypes, the underwool peak abscissa is between those of argali and mouflon and the influence of domestic genotype seems not to manifest. However, the peak corresponding to kemp is distinctly displaced to the left so that the abscissa of maximum is 135 μm, while that in the wild species is in the range 151–214 μm. Thus, the "domestic component" of the complex hybrid genotype does not distinctly influence the position of underwool hair peak but seriously limited the maximal thickness of the kemp (not more than 200 μm). Separation of underwool and kemp peaks in the diameter distribution curve of this hybrid is more distinct than in mouflon or domestic sheep: within the diameter range 24–76 μm, hardly any hairs are met.

The lack of hair diameters in the range of a dozen or two micrometers between the massifs of thin and

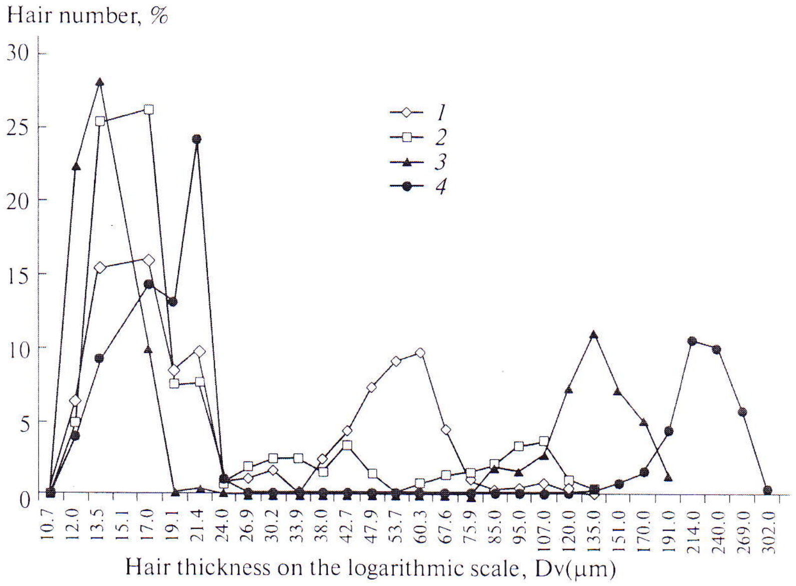

Fig. 3. Comparison of distribution of hairs among the classes of diameters in lambs and grown up sheep of similar genotype. Abscissae axis—mean hair diameters of the classes on a logarithmic scale. Ordinate axis—proportion of the hairs fallen to every thickness class (%). *1*—third generation F3 hybrid of mouflon × argali called Sarsenkul (2-month-old lamb); *2*—complex hybrid with 1/2 blood of domestic sheep, 1/4 argali, and 1/4 mouflon blood called Sapar (2-month-old lamb); *3*—complex hybrid with 1/2 blood of domestic sheep, 1/4 argali, and 1/4 mouflon blood called Nauryzgul (grown up animal); *4*—F1 hybrid of mouflon × argali called Bota (grown up animal).

thick hairs allows us to suggest the terms "underwool subpopulation" and "kemp subpopulation" of hairs.

The limits of underwool subpopulation on the hair diameter distribution curve with logarithmical abscissa scale must be the thinnest hair diameter and the diameters class where the ascended curve descended again close to the abscissa scale. For kemp subpopulation, the left limit must be the point where the curve starts to ascend over the abscissa scale as the diameter increases and the right limit must coincide with the absciss of the largest diameter class.

For example, in mouflon underwool, the subpopulation extends from hair diameter 11 to 24 μm and kemp subpopulation extends from 85 to 214 μm. In the complex hybrid, the corresponding limits were 11–19 and 85–214 μm, while that in domestic sheep underwool population is presented by the wide range 11–48 and kemp subpopulation is presented very poorly within the range 54–135 μm.

One can see from the table data that, in the course of sheep domestication, redistribution of the hairs among the diameter ranges took place: there is a definitely increased proportion of hair diameters within the range 20–45 μm (approximately 2/3 of all hairs), especially in the narrow range 20–22 μm. The serious decrease of the proportion of the thickest (more than 100 μm) and thinnest (less than 20 μm) hairs corresponded to this increase. Argalis differed from the single mouflon studied by an essentially lower proportion of hairs with diameters 45–99 μm but a higher proportion of hairs with diameters more than 200 μm.

The hybrids of wild species differed from original species by a lower rate of the thinnest hairs (10–14 μm) and, at the same time, by increased proportion of intermediate hair diameters 20–45 μm, thus displaying the same tendency as domestic sheep but expressed far less strongly.

At last, one of the hybrids with domestic blood, unlike hybrids of two wild species, had hair diameter distribution even more "wild" than original wild species except the highest diameter limit: no hairs with a diameter more than 200 μm are met as in domestic sheep.

In hair clusters clipped soon after moulting took place in June, the proportion of the thickest kemp is very high. This happens because kemp regeneration take place after moulting first of all, and, for the most part, the thickest kemp are included in a hair cluster clipped while underwool hairs are presented in a low proportion.

Some peculiarities of hair diameter distribution in lambs (2-months-old) with still not fully matured hair cover are presented in Fig. 3. The lack of hair diameters from 24–27 to 76–120 μm that separates underwool and kemp massifs of grown up sheep with similar genotypes is not characteristic for the lambs. Moreover, in the lamb with only wild genotype, there exists a well-expressed peak looking like kemp subpopulation but falling in hair diameter range 38–76 in which hair diameters are practically absent in wild grown up sheep.

In the lamb with domestic blood admixture, even two "quasikemp" subpopulations are likely to appear: hair diameter ranges 27–48 and 60–135 μm. This means that distinct separation of underwool and kemp hair massifs takes place in the course of "maturation" of the hair cover with age, perhaps partly by hair thickening of the lamb hairs of the range 27–76 μm up to the diameters characteristic for the massif of grown up sheep kemp massif. In grown up sheep, kemp subpopultions fall in the ranges 151–302 (wild blood only) and 85–191μm for the hybrid with 1/2 domestic blood.

Hair diameter at every moment depends upon: 1—dimension of hair papilla secreting correspondingly more or less proliferation factors and supporting in this way a certain cambium volume of hair follicle (bulb) around itself [1, 4], 2—hormonal status of the organism (cortisols, thyroid hormones, etc.). Papilla original dimension might be determined by the number of embryonal dermal cells aggregated perhaps by ameboid migration to the forming attraction centers. Such cell migration to attraction centers was described for mixomicetes (in this case, cyclic adenosine monophosfat being the attractant) [5]. The problem of nature of chemical agents of transduction chains detected in hair bulb papilla and involved in hair follicle induction was mentioned in a brief review by G.E. Rogers [6].

The decrease of hair diameter variation range in the course of domestication may be caused by a single or several gene mutations affecting cell migration to developing papillas and keeping these mutations in a selection process.

At two-months-old, lambs, as in domestic sheep, rather many hairs of the diameter range 24–76 μm are present which are but seldom met in grown up argalis and argali × mouflon hybrids but are present in grown up carpet domestic sheep. This means that, by the age of two months, lamb hairs do not reach the final thickness because (1) the papillas go on growing even after this age and do not reach final dimensions, or (2) perhaps cambium cells still are not capable to react at full scale on the papillas stimulation, or (3) stimulation is still feeble. In any case, argali lamb hair cover parameters resemble those of grown up domestic carpet sheep. The question may be asked whether domestic hair cover is the result of a "fixed" juvenile state of wild hair cover.

CONCLUSIONS

(1) Distribution of hairs among the classes of diameters in grown up sheep of wild species—argali (*Ovis ammon*) and mouflon (*O. musimon*) and their hybrids—is characterized by two maxima corresponding to underwool and kemp subpopulations between which there are but little intermediate hairs.

(2) Judging from carpet sheep breeds, underwool hair subpopulation displaced to the increased higher diameters in the course of domestication, while kemp subpopulation became less expressed (the thickest hairs disappeared) and essentially increased the frequency of the hair diameters intermittent between the two subpopulations.

(3) Grown up wild species × domestic sheep hybrids keep good enough kemp subpopulation though it is displaced to the lower hair diameters.

(4) In two-month-old argali lambs, the hairs of kemp subpopulation do not reach their final thickness and the distribution of hairs among the classes of diameter as a whole partly resembles that of grown up domestic carpet sheep.

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