Ann. Génét. Sél. anim., 1978, **10** (4), 503-506.

Hemoglobins of the *Corsico-Sardinian* Mouflon (*Ovis musimon*) and their implications for the origin of Hb A in domestic sheep (*Ovis aries*)

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Summary

The hemoglobin A allele was identified in the Corsico-Sardinian (European) mouflon by starch-gel electrophoresis. Since no other form of wild sheep have been identified as maintaining the A allele in its gene pool, and since HbA has been associated with the advent of domestication, two theories are proposed on the origin of the A allele in the European mouflon.

Hemoglobin A arose either by a mutation after isolation of islandic wild sheep, or, the European mouflon arose by feralization from archaic domestic strains which maintained the Hb A allele. The means, time of arrival and origin of the European mouflon to Corsica and Sardinia are discussed.

Introduction

Polymorphism of hemoglobin occurs regulary in breeds of domestic sheep and results in five electrophoretically separable protein zones (HARRIS and WARREN, 1955; EVANS *et al.*, 1958; VASKOV and EFREMOV, 1967; STORMONT *et al.*, 1968). The common adult hemoglobins are Hb A and Hb B. A rare adult type is designated Hb D, and the one fetal hemoglobin is Hb F. Hemoglobin C has been associated with severe anemia in sheep and apparently replaces Hb A. Only Hb B has been identified in wild sheep (*Ovis musimon, O. orientalis, O. ammon, O. dalli* and *O. canadensis*) (LAY *et al.*, 1971; NADLER *et al.*, 1971*a*; SPILLETT *et al.*, 1975 and BUNCH and VALDEZ, 1976). Consequently Hb A has been considered to have originated with a mutation that occurred during the domestication of sheep (NADLER *et al.*, 1971*b* and 1973).

Although Hb AB has been occasionally observed in captive populations of European mouflon (unpublished data) in the United States, an inability to trace the lineage of these sheep has equivocated interpretations that the A allele is carried in the *O. musimon* gene pool. In this report we describe the hemoglobins of 16 *Corsico-Sardinian* (*O. musimon*) mouflons kept in France.

Materials and methods

According to existing records, the first pair of Corsican mouflons were brought into the *Ménagerie de Jardin des Plantes* (a branch of the « *Muséum national d'Histoire naturelle* ») in 1920. Another female from Corsica was admitted in 1923. In 1932, a pair of Sardinian mouflons were acquired from a German merchant(1). The flock was then removed to the then newly created *Zoo de Vincennes*, 6 km East from the center of Paris where it is still mainly located. Since the flock reproduced well, many offspring have been sold out. Today, about 13 adult females and five adult males remain at the *Muséum*.

Blood samples from 16 mouflons (*O. musimon*) were analyzed. All the animals were direct line descendants from the population of mouflon created nearly 60 years ago at the *Muséum*. Four of the sampled adult rams were from the *Muséum* stock, the remaining 2 rams and 10 ewes belonged to a satellite collection at the *Institut National de la Recherche Agronomique, Laboratoire des Pelages, Toisons et Fourrures*, Jouy-en-Josas, France.

Hemolysates were prepared by washing heparinized blood 3 times in physiological saline and then lysing the red blood cells with distilled water. Horizontal starch-gel electrophoresis was used to separate the hemolysates. Hemoglobins were identified against an Hb AB standard.

Results

The starch-gel electrophoresis separated the mouflon hemolysates into Hb AB and Hb B. The four rams maintained at the *Muséum* had the heterozygous AB hemoglobin. The *Institut National de Recherche Agronomique* mouflons had the homozygous B.

Discussion

Cytological studies by NADLER *et al.* (1973) have confirmed that the mouflons (European: Corsican and Sardinian and Asiatic: Armenian) have a diploid chromosome number of 54 and a karyotype consisting of 3 pairs of biarmed chromosomes, 23 pairs of acrocentric chromosomes, a large acrocentric X and a minute, biarmed Y. Similarly, domestic sheep maintain a chromosome number of 54

(1) These probably originated from the Sardinian mouflon introduced by Prince Eugen in Austria as early as 1840, and subsequently introduced into several forests in eastern Europe up to the Crimea (ZEUNER, 1963).

and a karyotype which is indistinguishable from that of the mouflons. Consequently, the mouflons (or a mouflon-like wild sheep) have been purported to be ancestral to domestic sheep (NADLER *et al.*, 1973).

Since the Hb A allele has been reported to occur only in the European mouflon gene pool, its origin is open to conjecture. One possible hypothesis is that the A allele arose spontaneously once the islandic sheep became isolated in Corsica and Sardinia. Alternatively, it may have become established in the Corsico-Sardinian mouflon gene pool when the wild sheep came into contact with domestic sheep endemic to the islands. The former hypothesis has less appeal since the closest living relative of the European mouflon (Asiatic or Middle Eastern Mouflon) still maintains only Hb B in its gene pool.

In contrast, an expansion of the latter theory would infer that the present Corsico-Sardinian mouflons are feral descendants or possible hybrids of primitive domesticated strains that maintained the Hb A allele in their gene pool. This inference appears to be more plausible and is strongly advocated by BACETTI (1964), POPLIN (1977) and THALER (personal communication). The logic to support this hypothesis is:

1) There were no wild sheep in Europe in the late tertiary, which was the only time frame during which the mouflon could have migrated to the islands.

2) Sheep (wild or domesticated) on Corsica and Sardinia as well as goats are only found in layers dating back not more than 6 000 years B. C.

3) Man's inhabitation of the islands is strongly associated with a wide substitution of fauna.

Consequently, a human introduction of a wild strain of sheep to the islands is much less probable than is the introduction of an archaic domesticated strain. Such a strain, however, probably maintained close affinity to its wild ancestor, which allowed for a quick reversion to a feral and then wild type. The archaic strain must have maintained the wild genes for coloration (which have apparently disappeared in the existing archaic Corsico-Sardinian domesticated strains (LAUVERGNE and ADALSTEINSSON, 1976) along with the genes for the hair coat structure that involves natural moulting. as found in the still living *Soay* sheep. This archaism is in accord with the hypothisized early introduction during the 6th millenary B. C. (GUILAINE, 1976). The earliest domestication of sheep in the Middle East appears to have occurred about 7 000 B. C. (DUCOS, 1977).

Sheep and goats arrived at the islands of Corsica and Sardinia at approximately the same time. The goats, however, did not become feral. This may be partially explained by the goat being more domestically advanced (DUCOS, 1977) and unable to compete with the more primitive sheep for the wild-type niche . Once the archaic sheep inhabited the unoccupied niches, they can be assumed to have evolved into the modern form of European mouflon.

Conclusion

Our confirmation of the coexistence of A and B hemoglobin alleles in the Corsico-Sardinian mouflon strain maintained at the *Museum national d'Histoire naturelle, Paris* substantiates the hypothesis that the Corsica and Sardinian mouflon represents a feralization of a very archaic strain of domestic sheep.

Acknowledgments

We are especially grateful to Drs. CHAUVIER, *Ménagerie du Jardin des Plantes*, Paris and ROUGEOT, *Laboratoire des Pelages, Toisons et Fourrures, Institut national de la Recherche Agronomique*, Jouy-en-Josas for providing blood samples of the Corsico-Sardinian mouflons.

The discussion has been greatly helped by Dr. THALER Laboratoire d'Évolution des Vertébrés Montpellier, France and Dr. F. POPLIN from the *Muséum national d'Histoire naturelle*, Paris.

Résumé

Les hémoglobines du mouflon Corsico-sarde (Ovis musimon) *et l'origine de* HbA *chez le mouton domestique* (Ovis aries)

L'hémoglobine A a été mise en évidence chez le mouflon *Corsico-Sarde* (mouflon européen) par électrophorèse sur gel d'amidon. Comme cet allèle ne se retrouve chez aucune autre forme de mouton sauvage et comme l'apparition de HbA semble consécutive à la domestication on propose deux interprétations pour l'origine de l'allèle A chez le mouflon européen : soit une mutation après isolement d'un mouflon insulaire soit que le mouflon *Corsico-sarde* dérive par marronnisation d'un mouton domestique assez archaïque mais portant déjà HbA. L'installation et l'origine du mouflon européen en Corse et Sardaigne est discutée.

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