

From Wild to Tamed and Back: demographic reconstruction of Sardinian sheep from whole-genome sequences

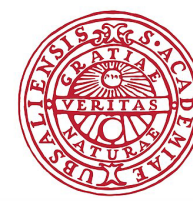
Viviana Floridia¹, Marianne Dehasque², Pedro Morell
Miranda³, Paolo Mereu, Monica Pirastru³, Nicolò
Columbano⁴, Salvatore Naitana⁴, Giovanni Giuseppe
Leoni³, Torsten Günther², Mario Barbato¹

¹*Department of Veterinary Science, University of Messina, Italy.*

²*Department of Organismal Biology, University of Uppsala, Sweden*

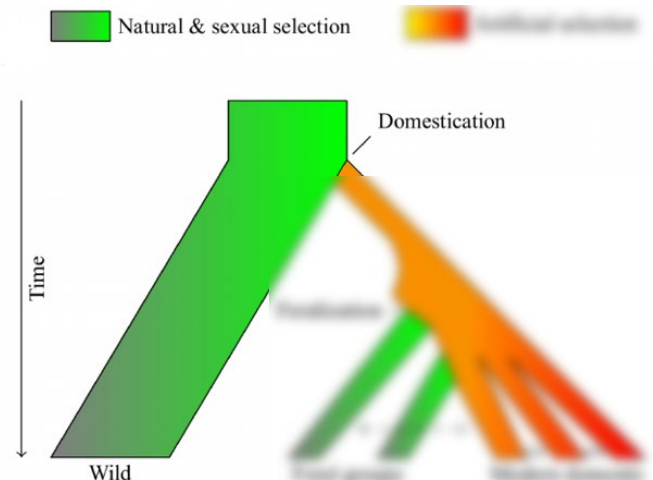
³*Department of Biomedical Science, University of Sassari, Italy*

⁴*Department of Veterinary Medicine, University of Sassari, Italy*



Background: from wild to tamed..

- **Sheep (*Ovis aries*)** were **domesticated** in the **Fertile Crescent** a first-time ca. **12,000** years ago (YA) and spread globally following human migrations.
- The **second wave of sheep domestication** (ca. **6,000** years ago) generated the **modern domestic sheep**.
- Sheep from the first domestication wave returned to a wild state and survived as feral populations, called **mouflon**.
- Mouflons are morphologically different from their modern domesticated counterparts.



Background: from wild to tamed and back



European mouflon: Sardinian and Corsican mouflon
(*O. gmelini musimon*)



Cyprus mouflon
(*O. gmelini ophion*)

What is the story of Sardinian mouflons?

We follow the taxonomic definition of the species *Ovis gmelini* Blyth, 1841



Background: story of Sardinian mouflons

No mouflon archeological remains are found in Sardinia dating before the first domestication wave



Feralization of first wave sheep and second domestication waves

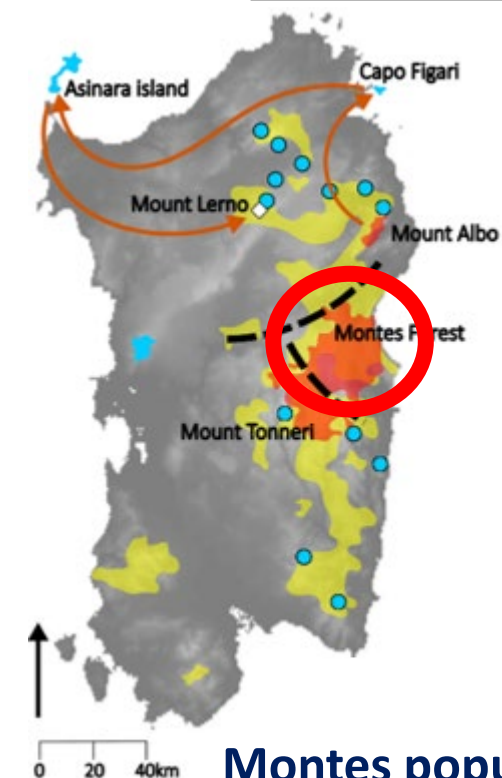


Due to over-hunting, mouflons disappeared in Europe but survived in Sardinia, Corsica and Cyprus.



18th century: the Sardinian and Corsica mouflon are brought back in continental Europe.

Background: Sardinian sheep and mouflon today



Mouflon distribution:

- **Montes Forest,**
- **Ogliastra,**
- Gennargentu,
- Supramonte,
- Mount Tonneri,
- Mount Albo
- North and Northwest (protected areas in the where mouflon has been reintroduced).



Sarda: milk production



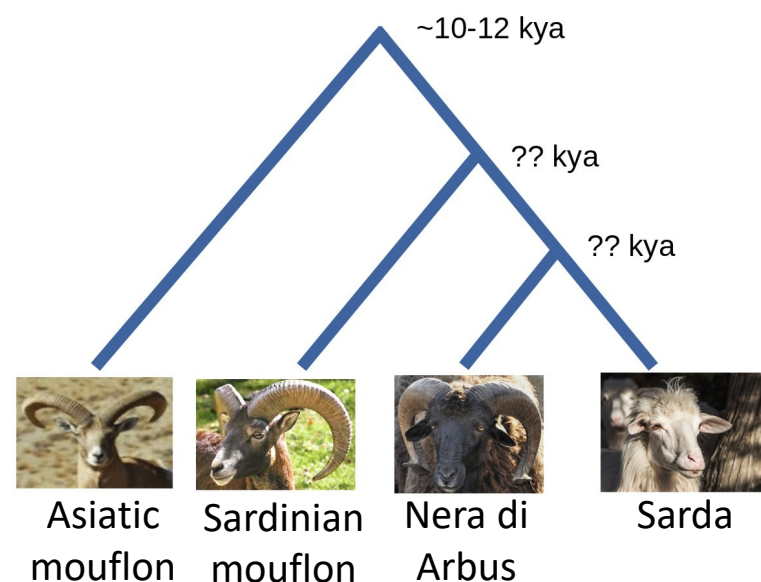
Nera di Arbus: local breed showing ancestral features.

Montes population showed ancestral mitochondrial haplotype in the phylogeny of European mouflon.

Questions and Aims

What we know:

1. Sardinian mouflons are the remnants of the first domesticated sheep (10-12,000 YA).
2. Two different Sardinian domestic sheep lineages: Sarda sheep and Nera di Arbus.



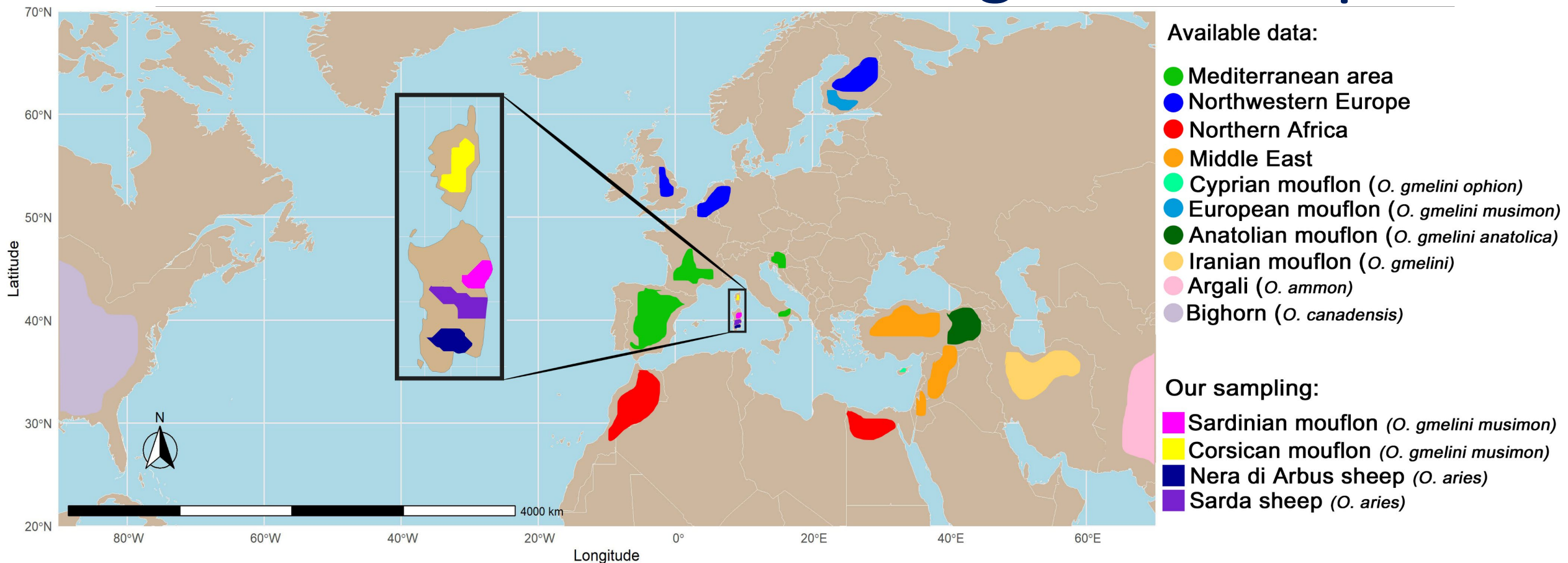
What we don't know:



1. What is the evolutionary relationship between the three Sardinian Ovis lineages?
2. When did domestic sheep separate from mouflon?
3. When did Sarda sheep separate from Nera di Arbus sheep?

AIM: Reconstruct the demography of Sardinian sheep using whole-genome sequence data

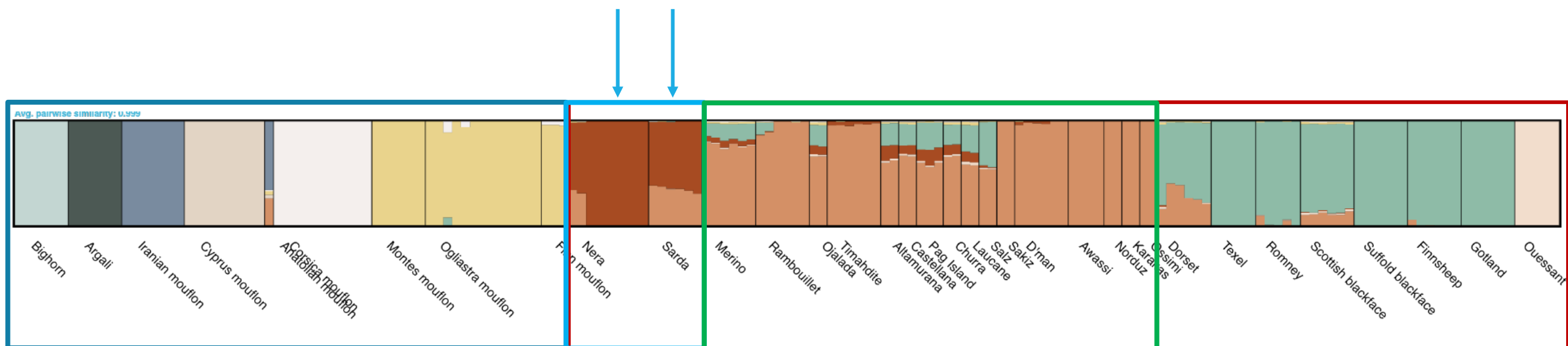
Material and Methods: Whole-genome sequences



Total: 176 individuals from 26 domestic breeds and 9 mouflon populations (feral and wild)

Results – ADMIXTURE

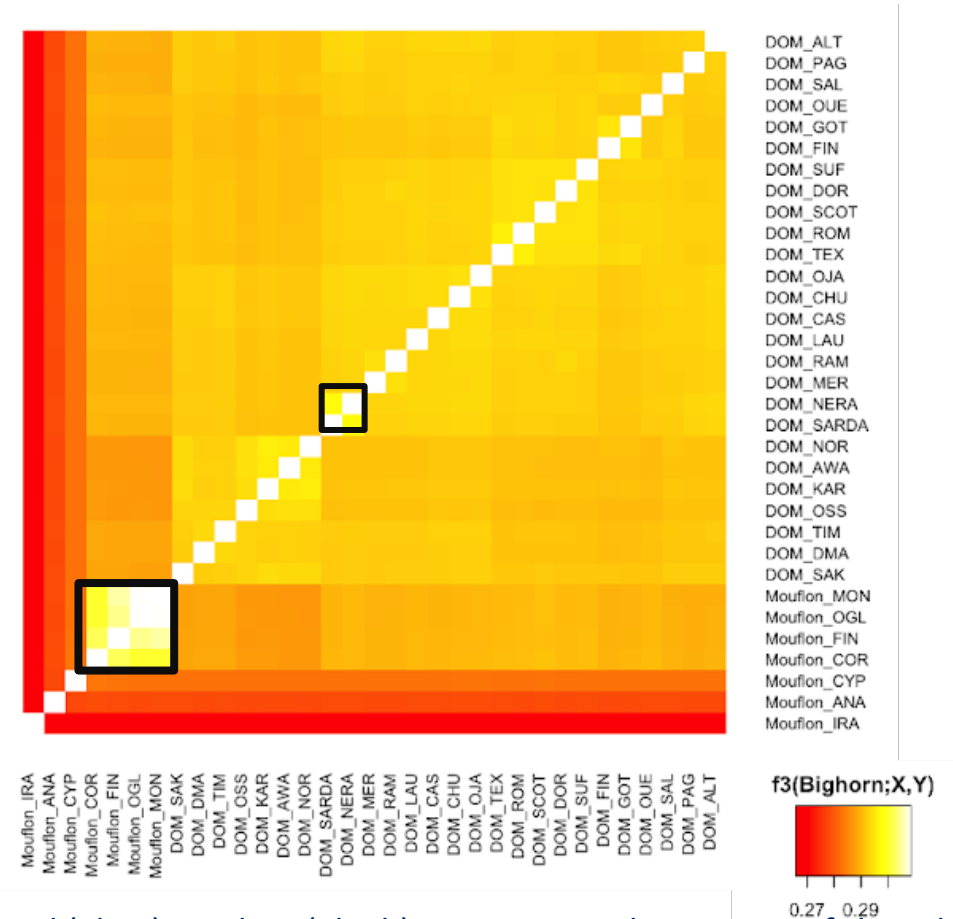
ADMIXTURE plot at K=10 (best CV-error)



- Wild and feral clustered differently from **domestic** populations.
- **Sardinian domestic breeds** share ancestry with **Mediterranean, North-African/Asian sheep breeds**.

Results - Outgroup-F3

- The mouflons from Finland, Corsica and Sardinia grouped together, confirming their common history origin.
- Domestic breeds share more genetic drift with each other than with wild or feral.
- Sarda and Nera di Arbus share a high percentage of genetic drift confirming their close relationship.

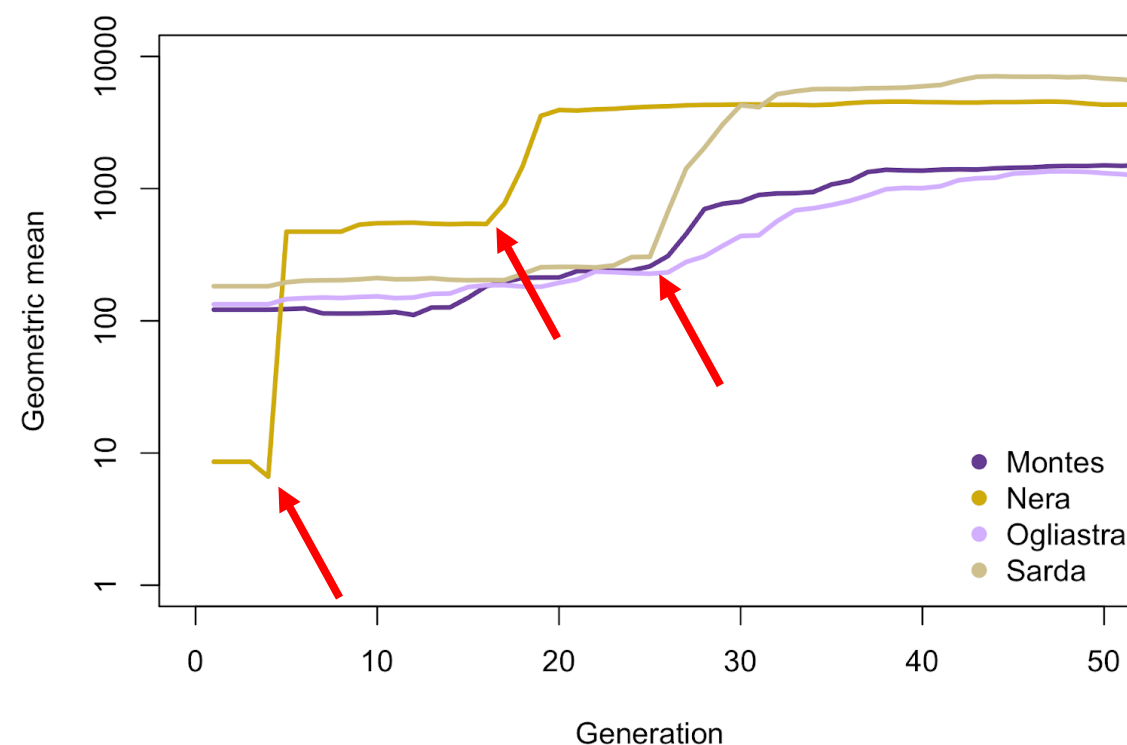


The scale goes from red (=low) to white (=high) to represent the amount of shared genetic drift.



Results – Effective population size (N_e)

- Sardinian mouflons and Sarda: bottleneck around 25 generations ago.
- Nera di Arbus: multiple reductions (5 and 15 generations ago)

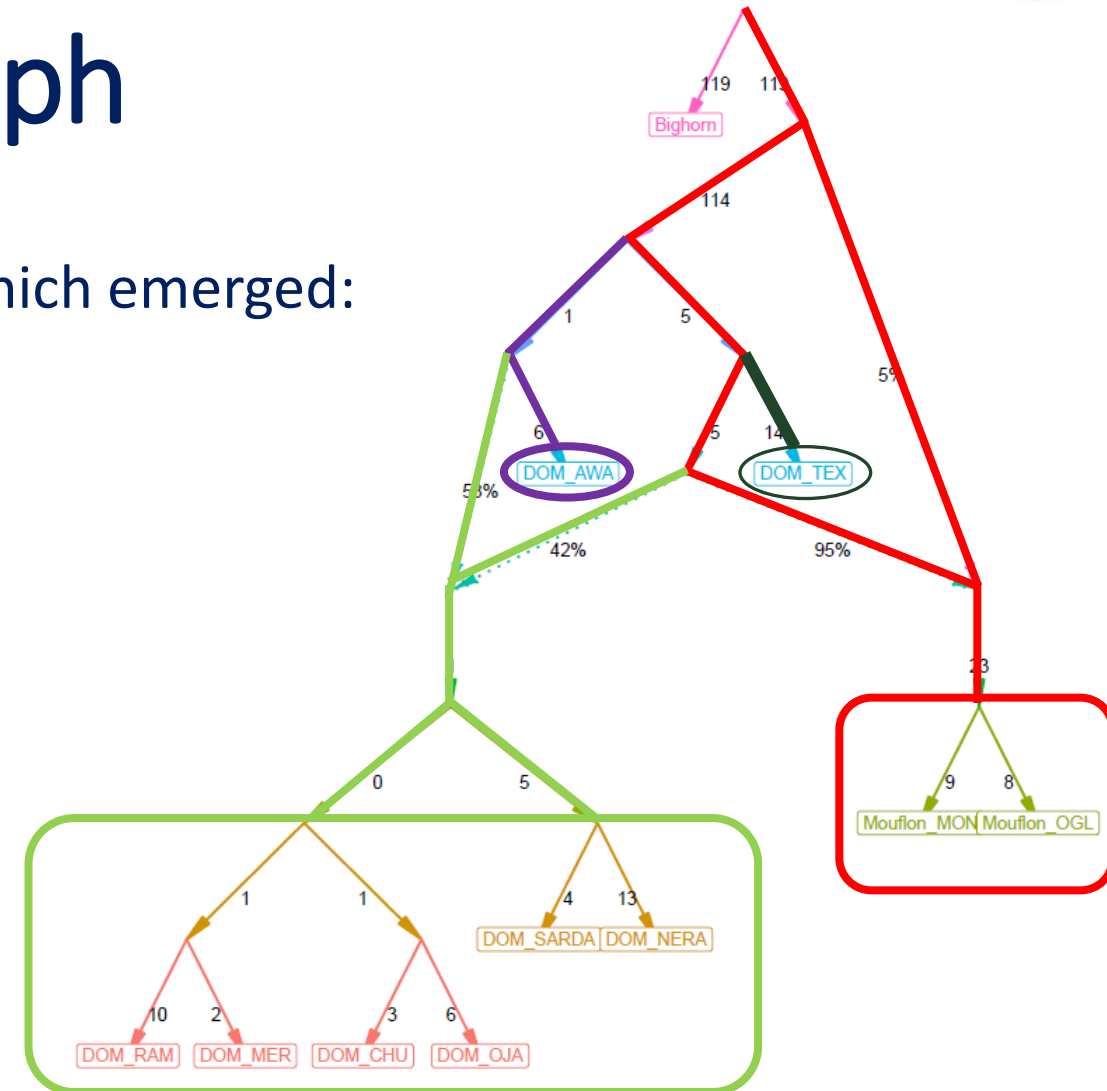


Results – Admixture graph

Historical path of the **Sardinian mouflons** ... from which emerged:

1. Middle East domestic sheep
2. Northwestern European domestic sheep
3. Mediterranean domestic sheep

No signals of gene flow between Sardinian mouflon and domestic Sardinian sheep.



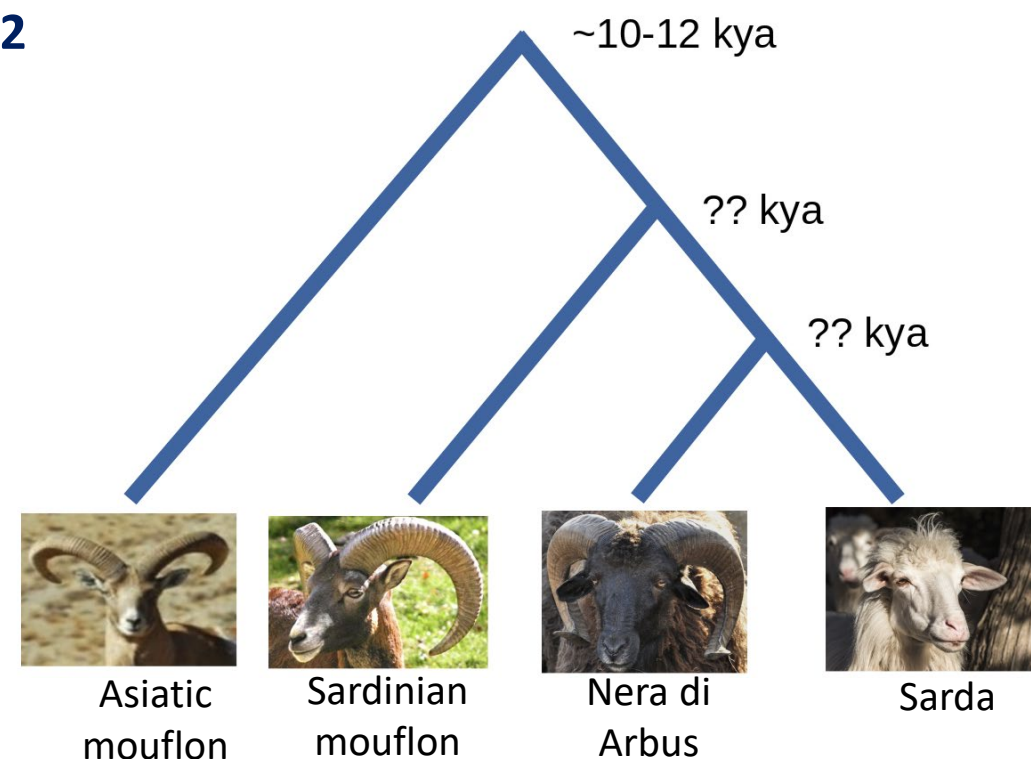
The numbers above the lines represent genetic drift units, whereas numbers next to dashed lines represent admixture proportions. Bighorn was used as the outgroup.



Results - Demographic Reconstruction

To reconstruct and date the evolutionary trajectories in the Sardinian island we used Momi2

Site frequency spectrum (SFS) is the distribution of allele frequencies of SNPs.



- The separation times were limited only by the order of the divisions and with an initial value set according to the beginning of domestication (12,000 YA).
- The generation time was assumed as 3 years, which is the average parental age at reproduction (Morell Miranda et al., 2023).



Results - Demographic Reconstruction

Sardinian mouflons-domestic sheep split

~6,700 YA

Sarda-Nera di Arbus split

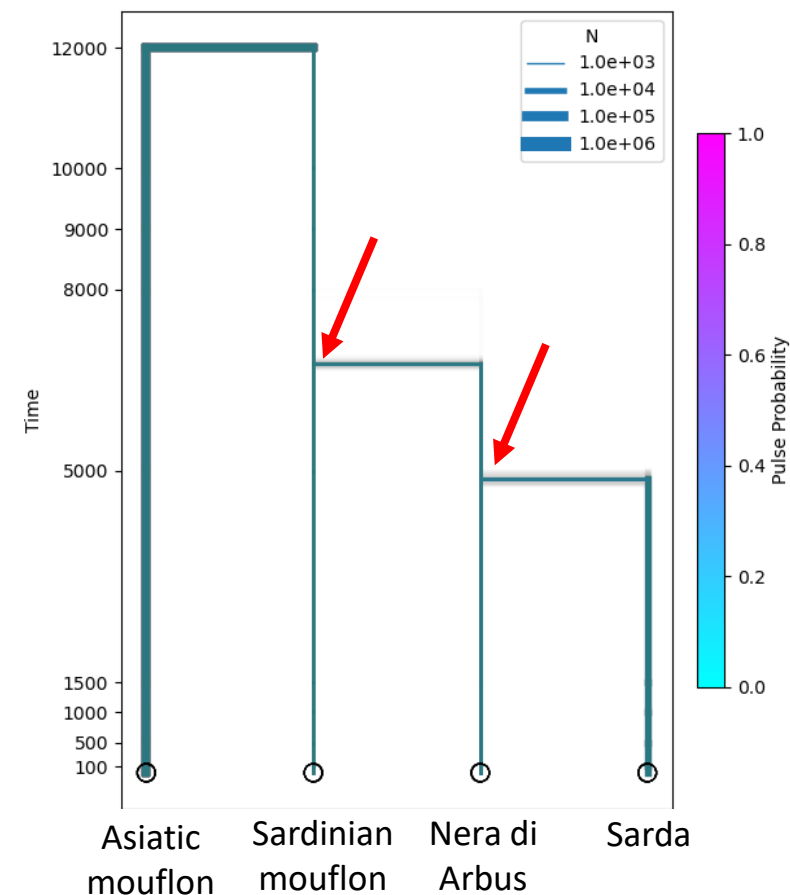
~4,800 YA

LogLikelihood

-65073866.86

KL divergence

0.0882031



Conclusion



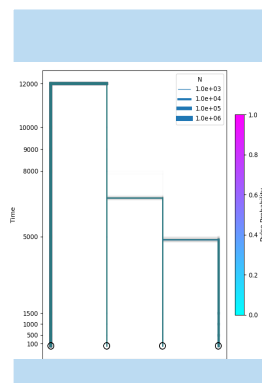
Sarda and Nera di Arbus look genetically similar despite their phenotypic differences.

No major mouflon contribution in Nera di Arbus.

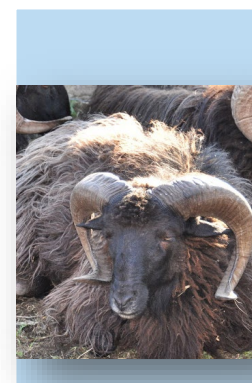
We identified three putative events of domestication from mouflons that might have contributed to generate the modern domesticated sheep.

Two ancestries possibly contributed to the formation of the Mediterranean domestic sheep breeds.

Future Directions

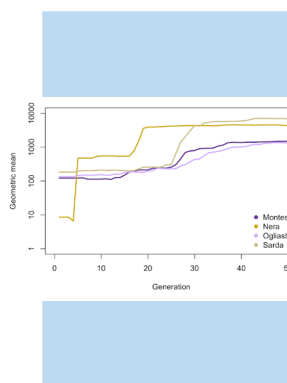


Improve model including bottlenecks and understand what historically happened in the period of the splits time.



Ancient DNA to look more deeply into the differences among Nera di Arbus and Sarda sheep.

Why Nera di Arbus shows ancestral traits.



Define the parameters to be used when we have both feral and domestic breeds.

Thanks



Dr. Mario Barbato



Dr. Torsten Günther



Dr. Marianne Dehasque



Dr. Pedro Morell Miranda

