



Unravelling the genetic diversity among Nubian, Anglo-Nubian, and Old English goat breeds



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Introduction

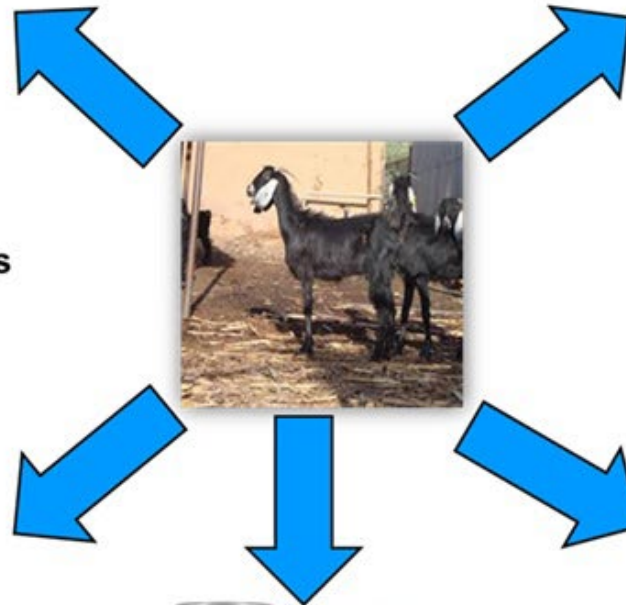
Importance of goats



Growing human populations



Source of protein



Adaptation to harsh environment



Poor man's cow



Trendy health food

Nubian, Anglo-Nubian, and Old English goats

■ Nubian goats¹

- Widespread across Algeria, Egypt, Sudan, Eritrea, and Ethiopia
- Milk and meat production
- Adapted to arid environment

■ Anglo-Nubian goats

- British breed
- Developed during 19th century from cross-breeding **Old English** with **Nubian** from Africa and **Jamunapari** goats from India²
- Exported to many parts of the world and is now found in more than sixty countries³
- Dairy or dual-purpose breed

■ Old English goats

- Native British breed
- Milk production

Nubian



Anglo Nubian



Old English



- 1) Assess **genetic diversity** and **genomic inbreeding** in Nubian goats compared to other goat breeds
- 2) Evaluate **genetic relationship across** different Nubian populations and to other goat populations
- 3) Identify **genomic regions undergoing positive selection** in Nubian, Anglo-Nubian, and Old English goats

- Genotypic data of **2523** goats from **61** populations
 - **Axiom Caprine 60K SNP chip**
 - **Illumina Goat SNP 52K chip**
 from AdaptMap¹, collaborators^{2,3}, and own genotyping⁴

Breed	Country	No.	500
Nubian	Algeria	88	
Nubian	Argentina	15	
Nubian	Egypt	150	
Nubian	Ethiopia	70	
Nubian	Sudan	177	
Anglo-Nubian	United Kingdom	29	
Old English	United Kingdom	54	
Old English	Ireland	31	

¹ Stella *et al.* (2018). *Genetics Selection Evolution* **50**, 61.

²Tarekegn *et al.* (2021). *Evolutionary Applications*. **14**, 1716–1731.

³ Robert Onzima. *Animal Genetics* **49**, 59-70.

⁴Rahmatalla *et al.* (2017). *BMC Genetics*. **18**, 92.

Diversity analyses

- Minor allele frequency (MAF)
- Observed (H_O) and expected heterozygosity (H_E)
- Nucleotide diversity (π)
- Inbreeding as Excess of homozygosity (F_{Hom})

VCFtools

VCFtools

10 kb windows using VCFtools

VCFtools

Genetic differentiation

- Pairwise genetic differentiation (F_{ST})
- Principal component analysis (PCA)

Hudson's method¹ using VCF tools

scikit-allel package

Signature of selection

- Run of homozygosity islands (RoH islands)
- Gene annotation

plink v1.90; top 0.01 percentile of frequencies as threshold
genes within ± 0.1 Mb from RoH islands

Genetic diversity & inbreeding within goat breeds



Population	No.	SNPs	MAF (%)	H _O (%)	H _E (%)	Nucleotide diversity (%)	F _{Hom} (%)
Nubian (Algeria)	88	46056	32.21	40.39	41.18	7.55x 10 ⁻⁴	7.69
Nubian (Argentina)	15	47561	31.83	39.41	42.05	8.11 x 10⁻⁴	10.78
Nubian (Egypt)	150	47264	28.62	36.01	37.46	7.11x 10⁻⁴	18.08
Nubian (Ethiopia)	70	47478	30.04	38.42	39.21	7.53x 10 ⁻⁴	12.72
Nubian (Sudan)	177	46399	30.32	38.44	39.06	7.23x 10 ⁻⁴	11.95
AngloNubian (UK)	29	46473	21.00	33.86	33.52	5.33x 10⁻⁴	33.91
OldEnglish (Ireland)	31	47390	24.16	26.98	36.15	6.15x 10 ⁻⁴	45.17
OldEnglish (UK)	54	46707	25.71	35.41	35.12	6.48x 10 ⁻⁴	20.41

- In Nubian populations:
 - Nubian (Algeria) have **highest genetic diversity** (highest MAF and H_O, lowest F_{Hom})
 - Nubian (Argentina) have **highest nucleotide diversity**
 - Nubian (Egypt) have **lowest genetic diversity** (lowest MAF and H_O, highest F_{Hom}), and **lowest nucleotide diversity**
- Anglo-Nubian (UK) have **lowest MAF** and **nucleotide diversity** across all breeds
- Old English (Ireland) have **lowest H_O** and **highest inbreeding** (F_{Hom}) among all breeds

Estimated pairwise fixation index (F_{ST})

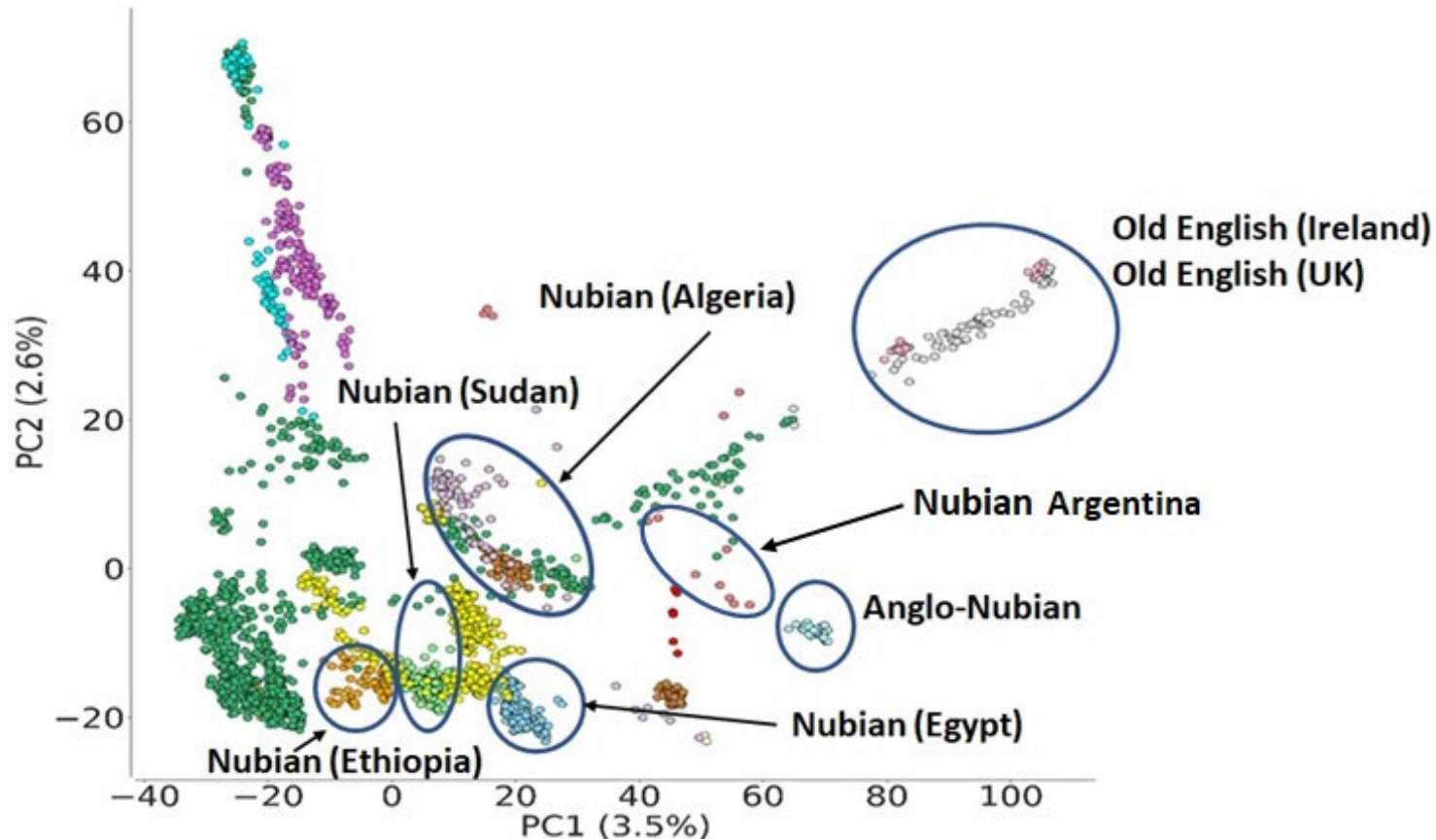


Populations	Nubian (Argentina)	Nubian (Egypt)	Nubian (Ethiopia)	Nubian (Sudan)	Anglo-Nubian (UK)	OldEnglish (Ireland)	OldEnglish (UK)
Nubian (Algeria)	0.05	0.06	0.03	0.03	0.16	0.16	0.14
Nubian (Argentina)		0.10	0.08	0.08	0.14	0.16	0.14
Nubian (Egypt)			0.06	0.05	0.18	0.20	0.18
Nubian (Ethiopia)				0.01	0.18	0.18	0.17
Nubian (Sudan)					0.16	0.18	0.16
AngloNubian (UK)						0.25	0.21
OldEnglish (Ireland)							0.08

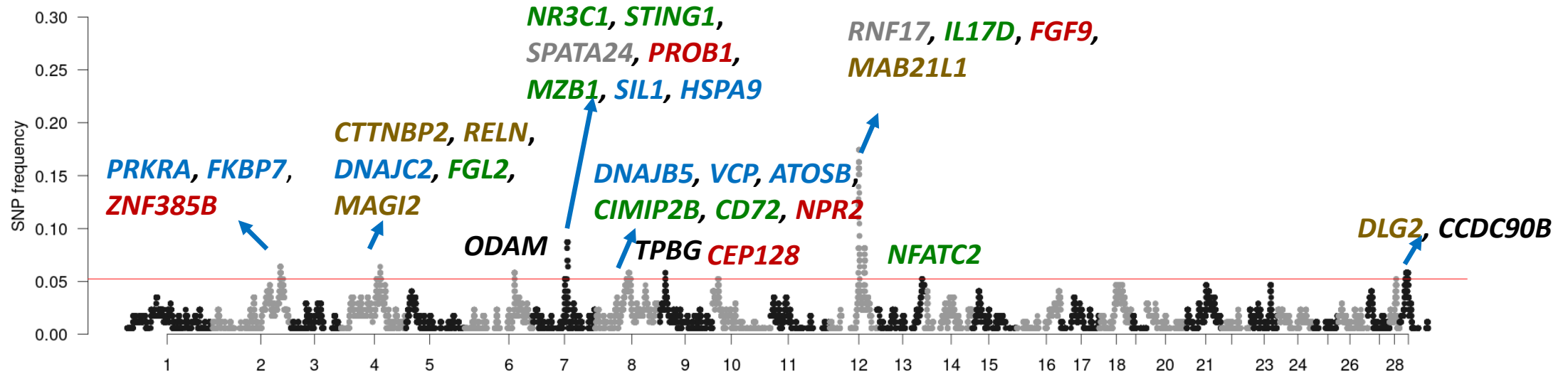
- **Nubian populations** (African countries) were closely related (F_{ST} values ranges between **0.01** to **0.06**)
- **Anglo-Nubian** goats exhibit **a high genetic distance** compared to other populations
- **Old English (Ireland)** goats are tightly related to their counterparts in UK

Results

Relationship between populations- PCA

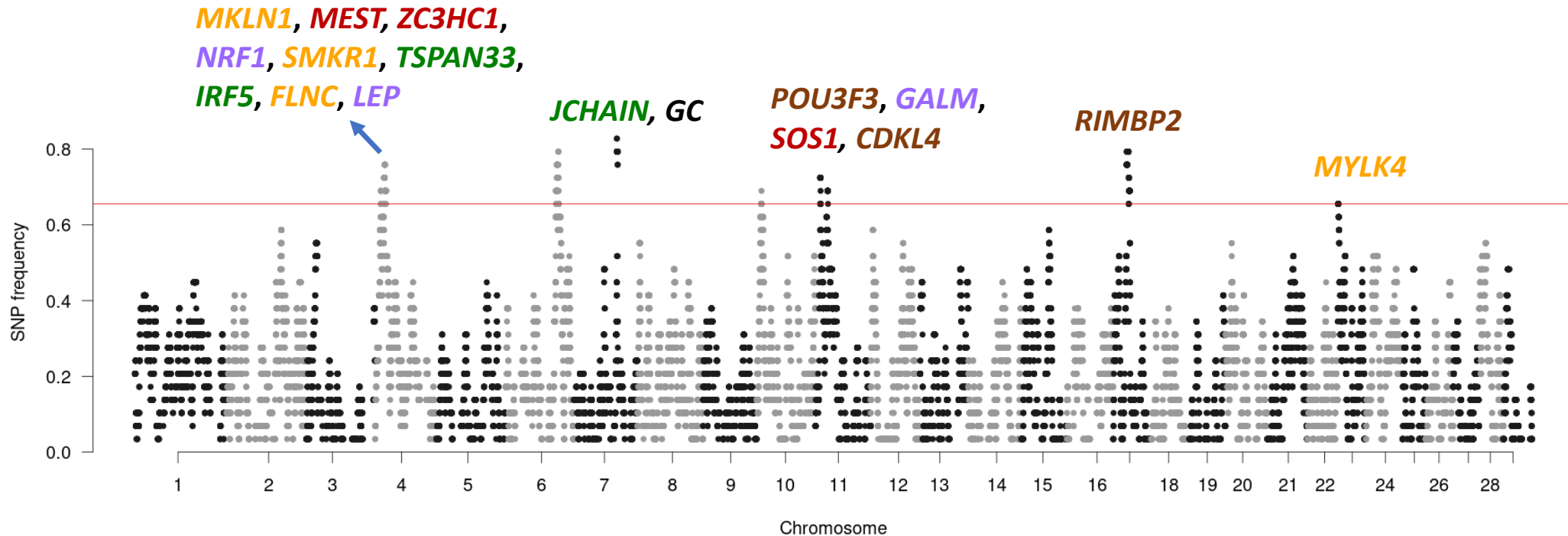


- **Nubian (Egypt, Ethiopia, Sudan)** each form distinct clusters (near Northern African populations)
- **Nubian (Algeria)** form dispersed cluster (near Eastern, Northern, and Southern African populations)
- **Old English (Ireland, UK)** are closely clustered
- **Anglo-Nubian** form a unique cluster between **Old English, African and middle east** goats

Signature selection (RoH islands) - **Nubian Sudan**

- *PRKRA, FKBP7, DNAJB5, VCP, ATOSB, DNAJC2, SIL1, HSPA9:*
- *ZNF385B, PROB1, NPR2, FGF9:*
- *FGL2, NR3C1, MZB1, CIMIP2B, CD72, IL17D, NFATC2:*
- *SPATA24, RNF17 :*
- *CTTNBP2, RELN, MAGI2, MAB21L1, DLG2:*

cellular heat stress responses and radiation
bone growth and cell proliferation
immune response (disease resistance)
spermatogenesis and reproduction
neurological functions and nervous system

Signature selection (RoH islands) - **Anglo-Nubian**

- *MKLN1, SMKR1, FLNC, MYLK4* : muscle development, structure (meat quality)
- *MEST, ZC3HC1, SOS1*: growth and development
- *TSPAN33, IRF5, JCHAIN*: immune response (disease resistance)
- *GC*: transport of Vit. D (skeletal strength, milk production)
- *POU3F3, CDKL4, RIMBP2*: neurological functions and nervous system
- *NRF1, LEP, GALM*: energy balance and metabolism (milk and meat production)

■ Nubian populations:

- Nubian (Algeria) goats have the **highest genetic diversity** and **lowest inbreeding**
- Nubian (Egypt) have the **lowest genetic diversity** and **highest inbreeding**
- Nubian (Sudan) have genes related **heat stress response** and **immune function**, which reflects their **high adaptability to harsh environments**
- Nubian goat populations in African countries are **genetically similar**

■ Anglo-Nubian:

- Anglo-Nubian show **a high genetic distance** with other populations
- Anglo-Nubian form a **distinct cluster** between Old English, African, and Middle Eastern goats
- In **Anglo-Nubian** goats, key genes were found for **muscle development**, **vitamin D transport**, and **energy regulation** highlight their effectiveness as **a dual-purpose breed**

■ Old English:

- Among all breeds, **Old English (Ireland)** have the **lowest genetic diversity** and **highest inbreeding**

Thank you for your attention!



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Nubian goats research farm

Questions?



DFG Deutsche
Forschungsgemeinschaft