

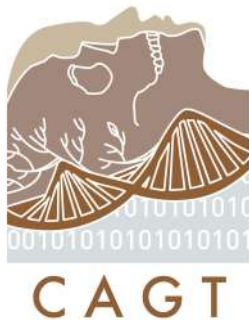
Ancient DNA, museomics and insect domestication



Pablo Librado, PhD

@IMP Athens

30/01/2025







50-250mg

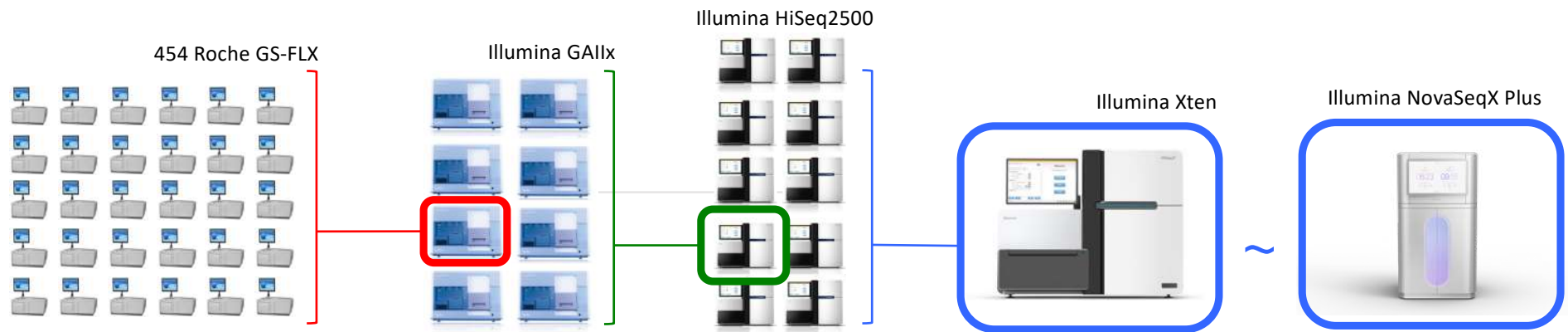
Ancient DNA Processing

Ultraclean Facilities



Ancient DNA Sequencing

Next-Generation DNA Sequencing



0.5M

250M

4G

30G

24G

0.5d

5d

5d

3d

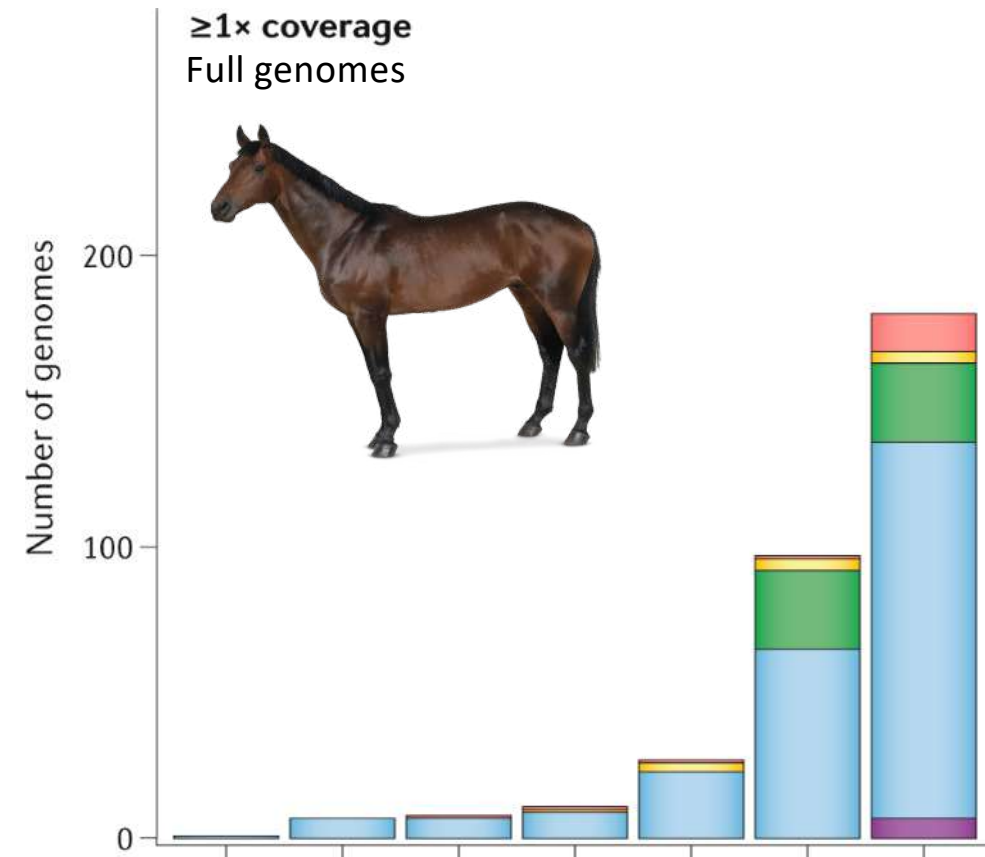
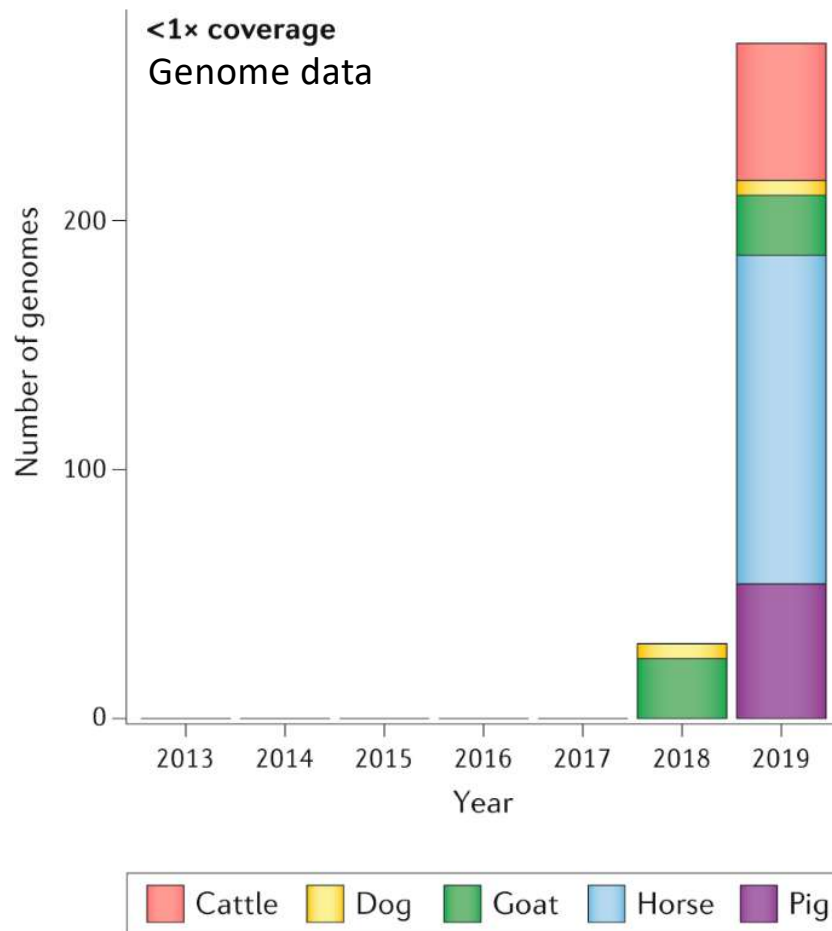
1d

2005

2023

In animals

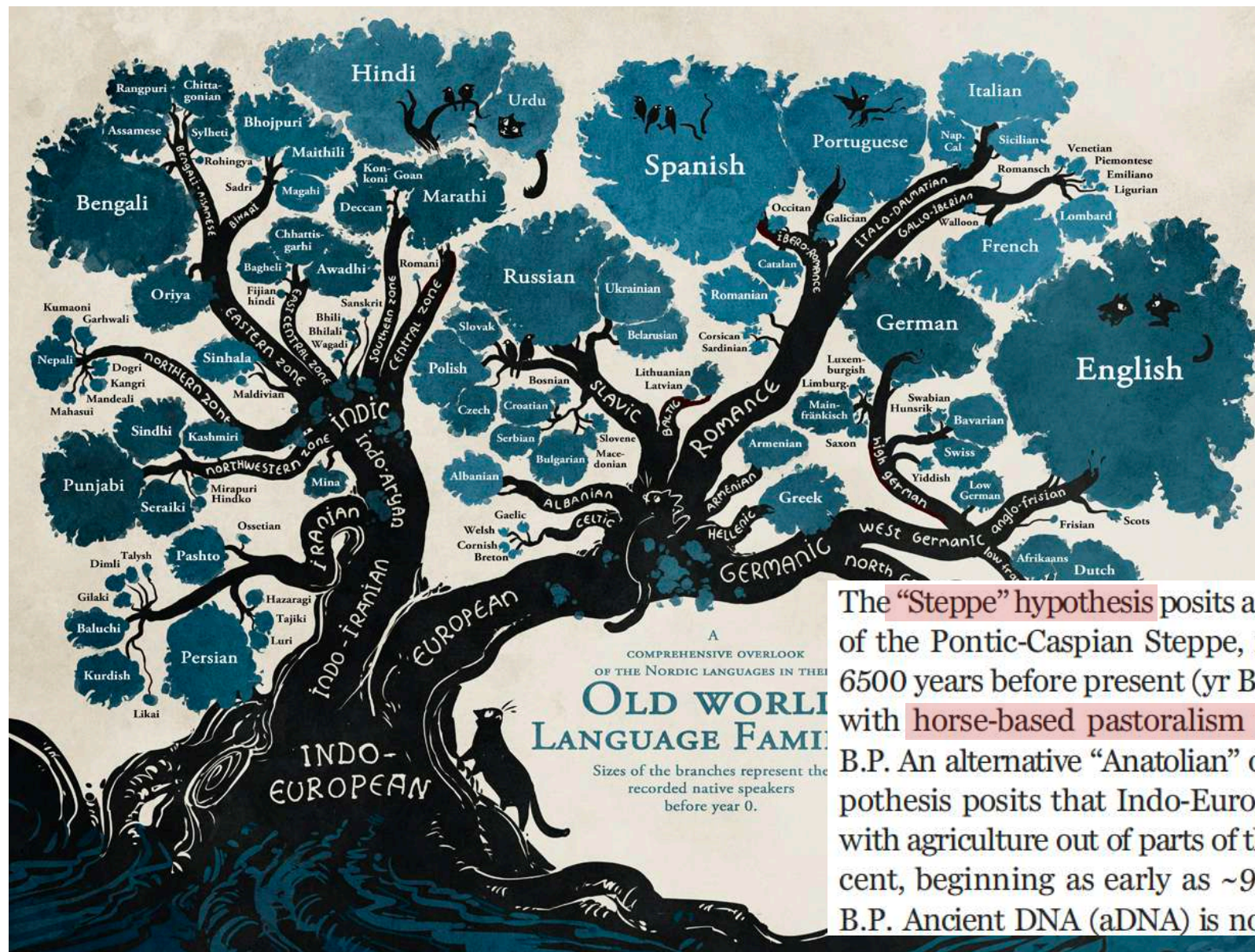
Frantz et. al 2020



Why horses?



The **horse (DOM2)** provided the fastest way of transportation during millennia, until the invention of motor engines

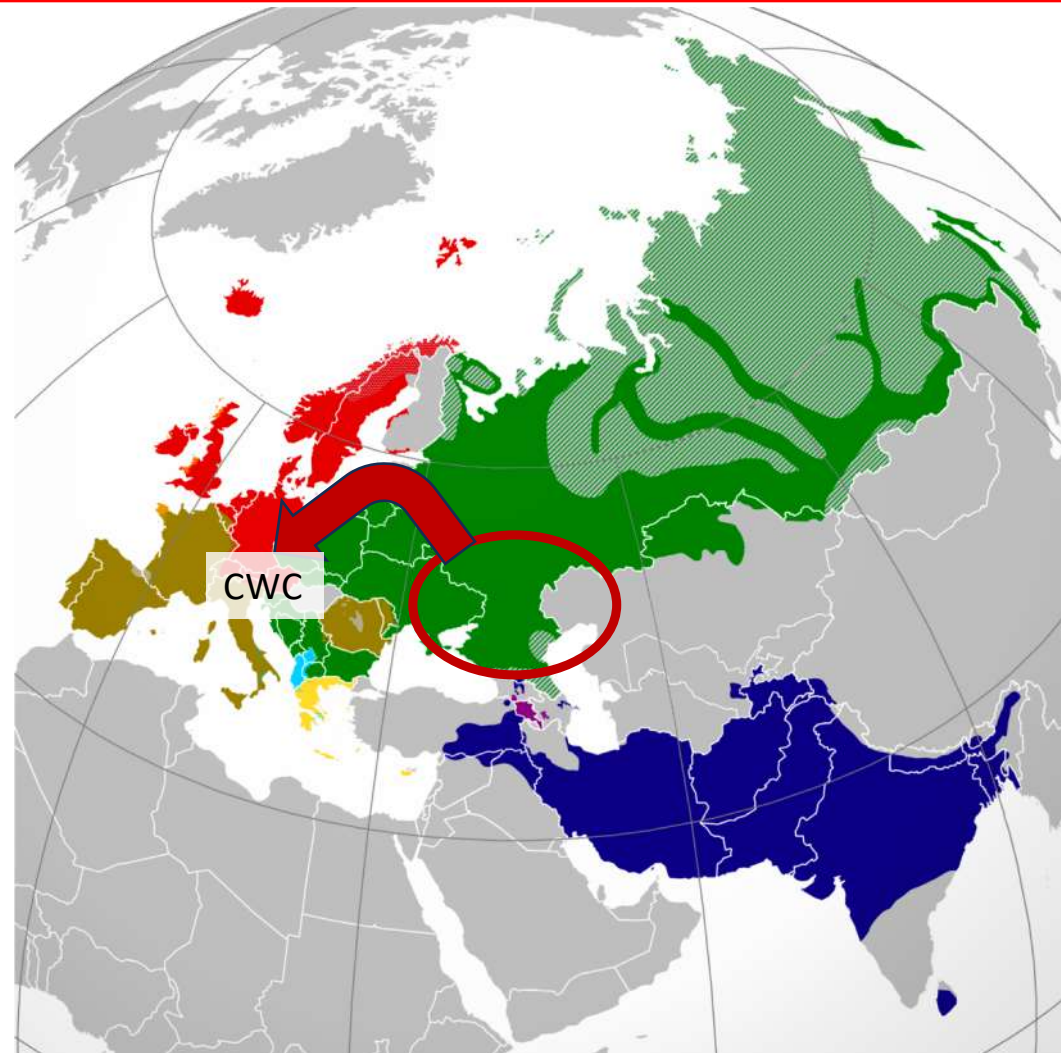


The “Steppe” hypothesis posits an expansion out of the Pontic-Caspian Steppe, no earlier than 6500 years before present (yr B.P.), and mostly with horse-based pastoralism from ~5000 yr B.P. An alternative “Anatolian” or “farming” hypothesis posits that Indo-European dispersed with agriculture out of parts of the Fertile Crescent, beginning as early as ~9500 to 8500 yr B.P. Ancient DNA (aDNA) is now bringing val-

Steppe hypothesis

Expansion of steppe pastoralists from the steppe, starting **5000YA: YAMNAYA**

2/3 of a present-day Central European person descends from that migration (5000YA)





Die Schlacht bei Wien 1683

1683

Ottoman vs. Holy Roman

The modern domestic horse (DOM2)



Domestic
(DOM2)

Hundreds of breeds

Large diversity of sizes, shapes and colors



The modern (~~wild~~) horse



Przewalski's

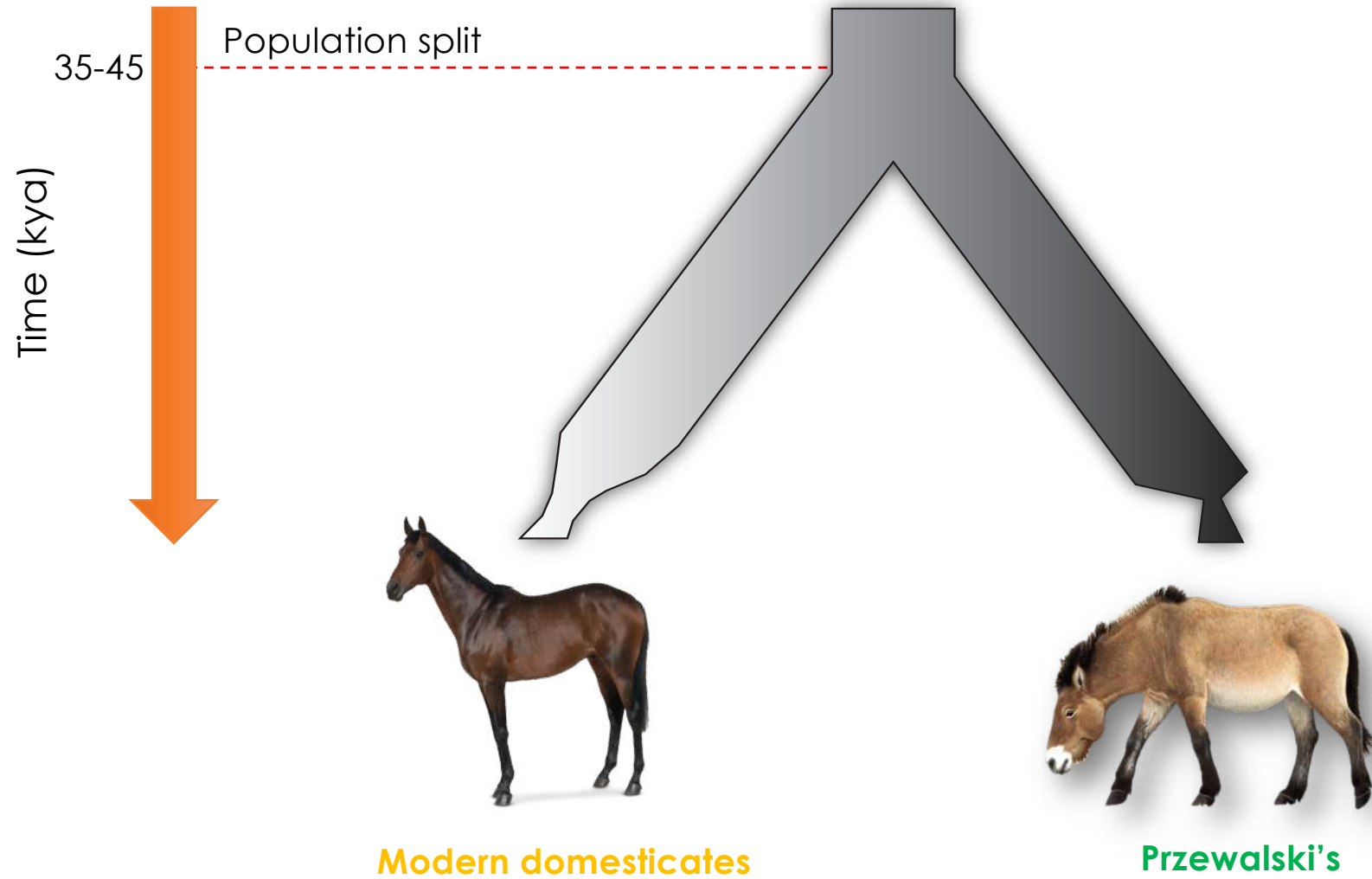
Critically endangered (IUCN)

2,100 individuals

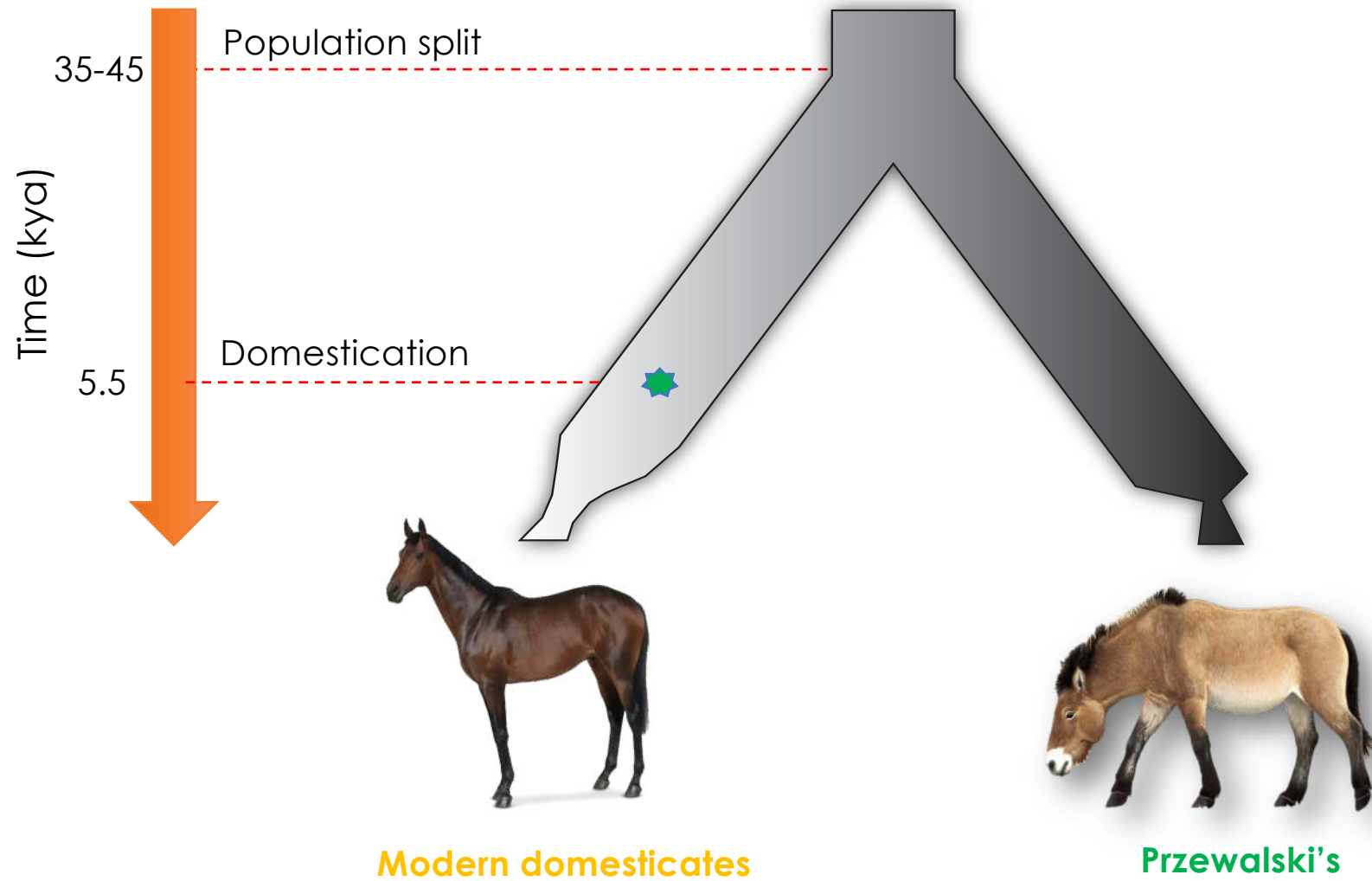
**Recovered from a stock of 12-16
individuals in zoos**

Reserves in Mongolia

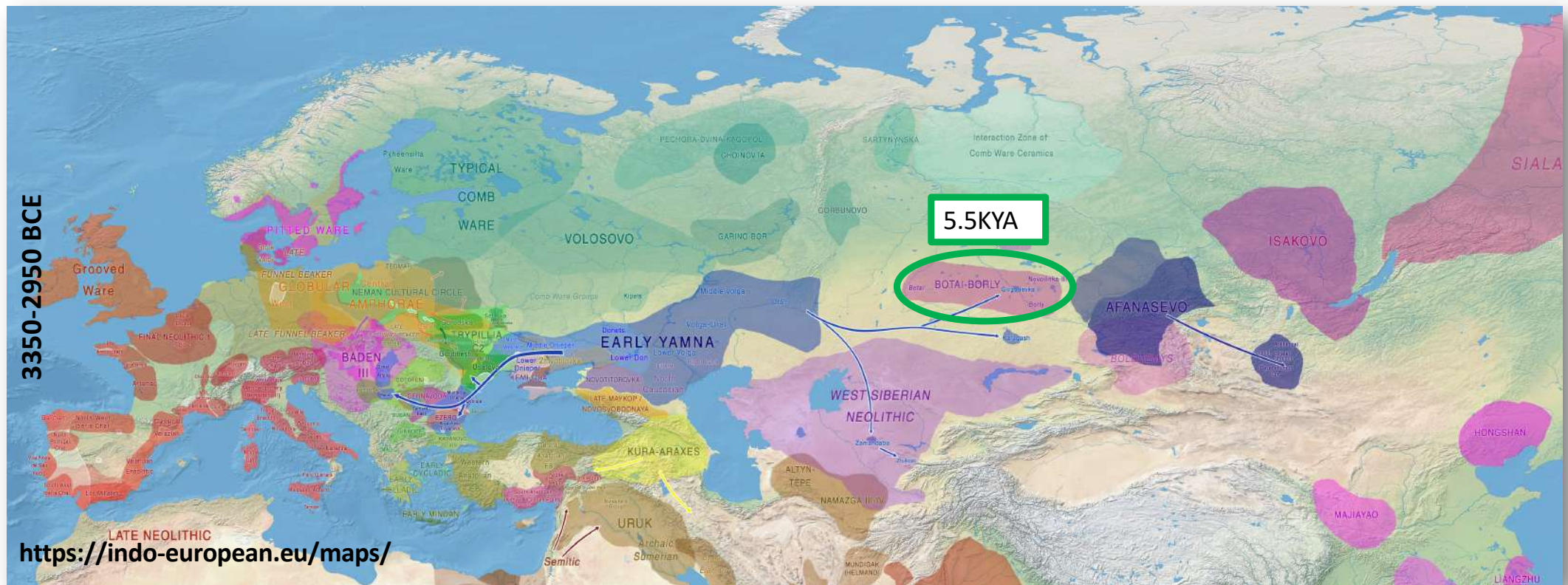
The relationship between modern horses



The relationship between modern horses



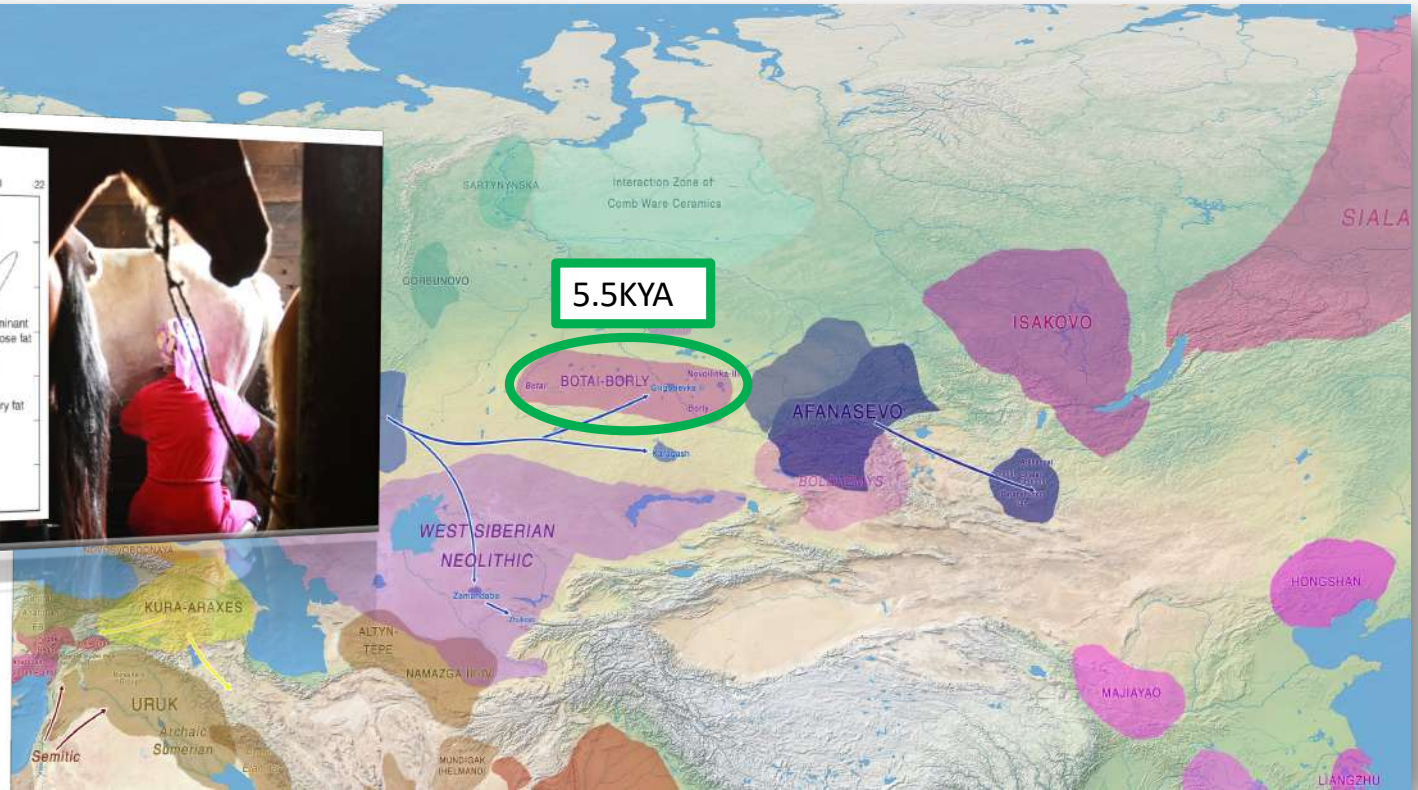
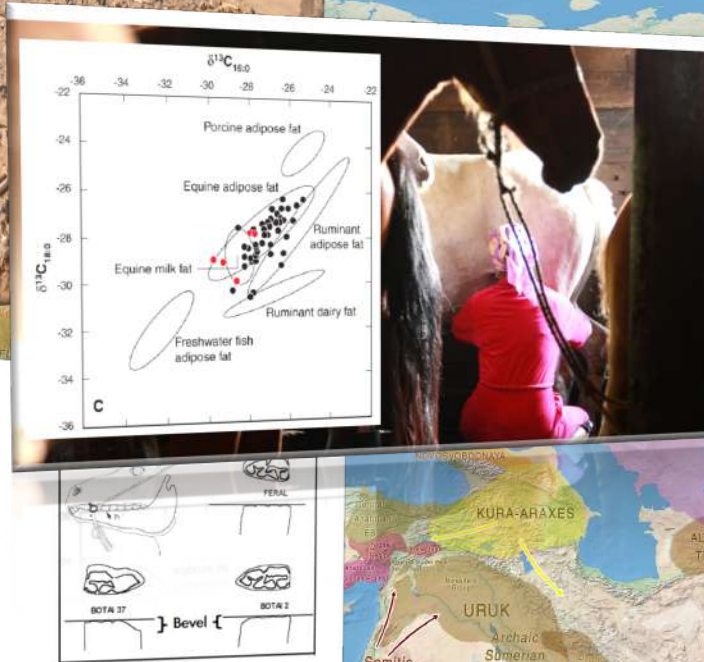
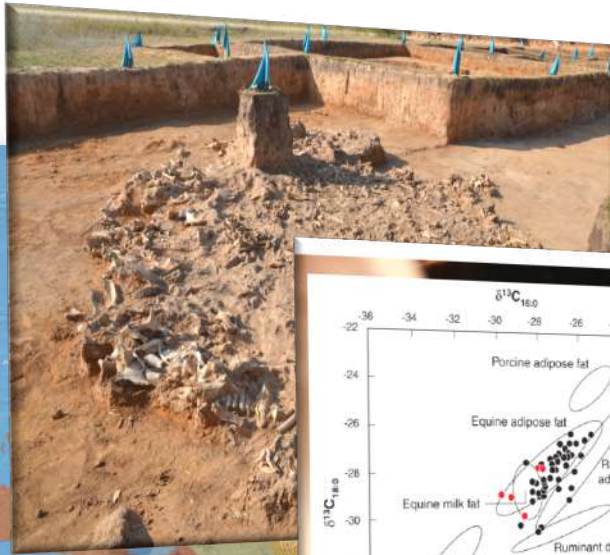
Horse domestication at **BOTAI**



Horse domestication at **BOTAI**

3350-2950 BCE

<https://www.britannica.com/place/Botai>

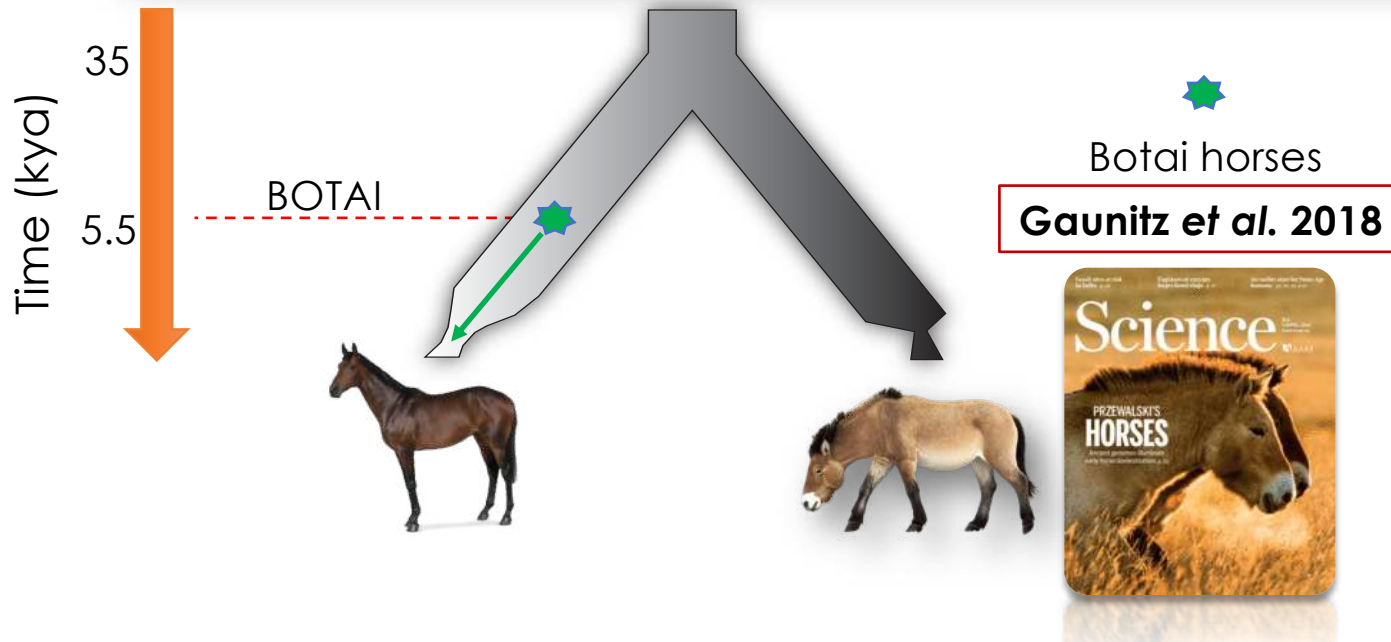


<https://indo-european.eu/maps/>

3350-2950 BCE

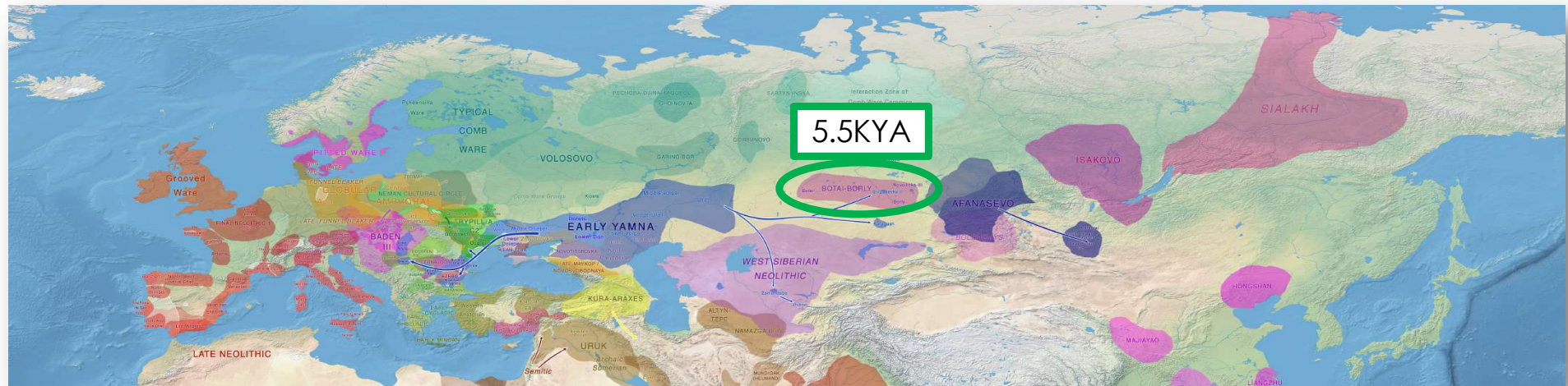


20 ancient Botai horses (5.5KYA)
+
A handful of Borly horses (5KYA)



<https://indo-european.eu/maps/>

3350-2950 BCE



3350-2950 BCE



<https://indo-european.eu/maps/>

3350-2950 BCE



The international journal of science / 28 October 2021

Index
Infectious
disease

nature

HORSE CODE

The genetic origins of the
modern domesticated horse

Gain of function

What do we learn by
giving dangerous
microbes extra abilities?

Battling the bootlegs

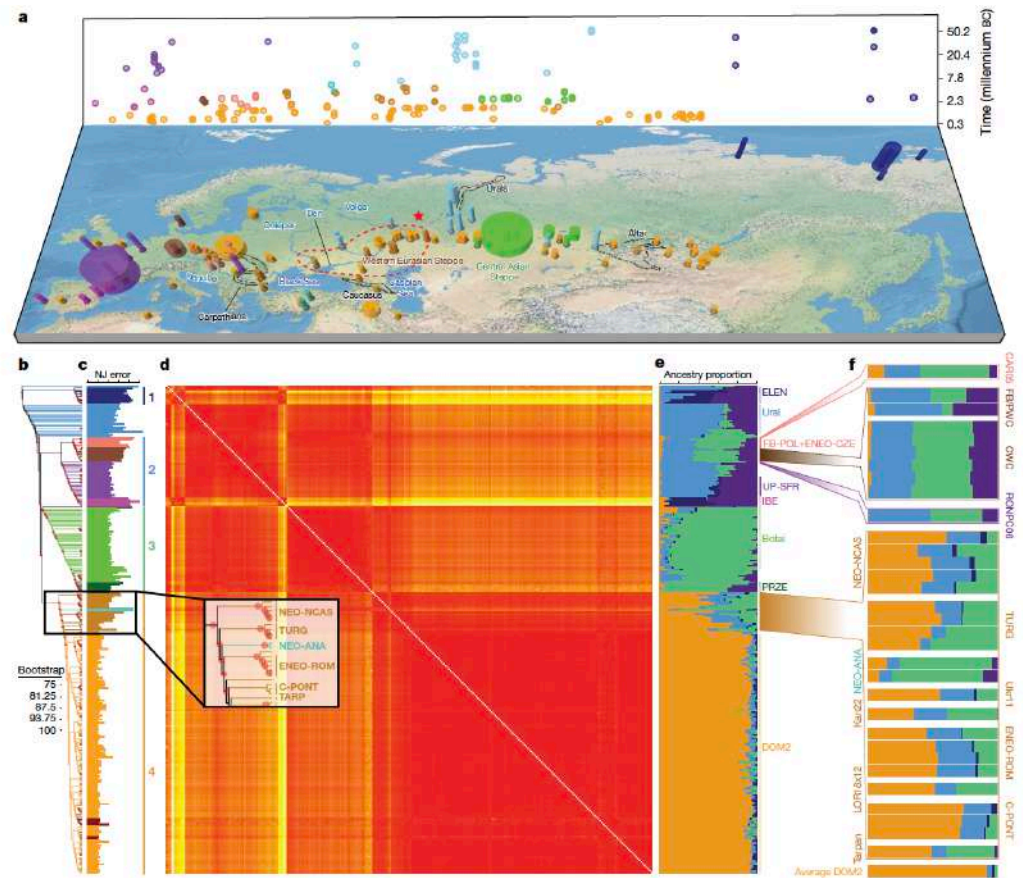
How to tackle the
Hydra of predatory
publishing

Thirsty work

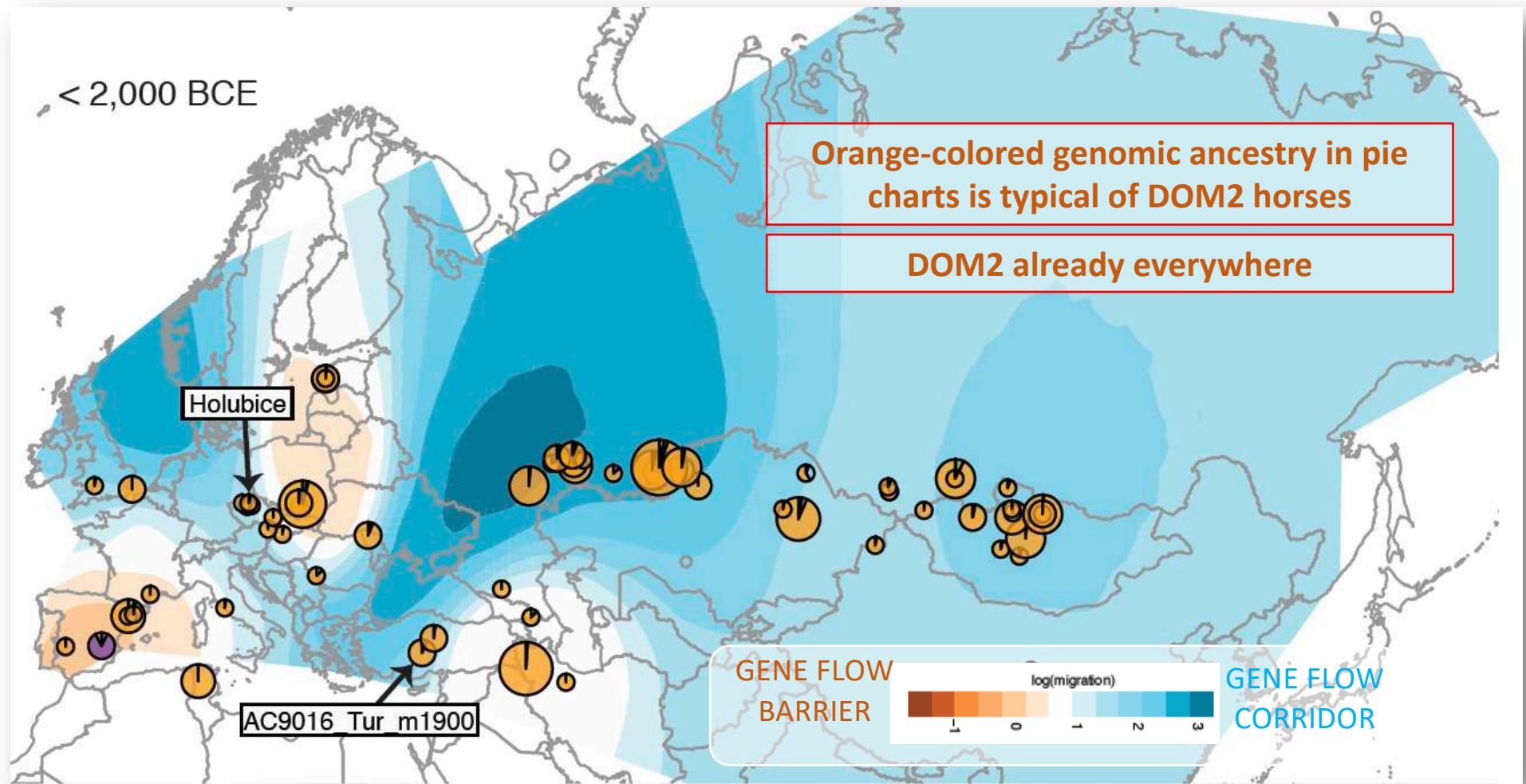
The global potential
for harvesting drinking
water from the air

Article

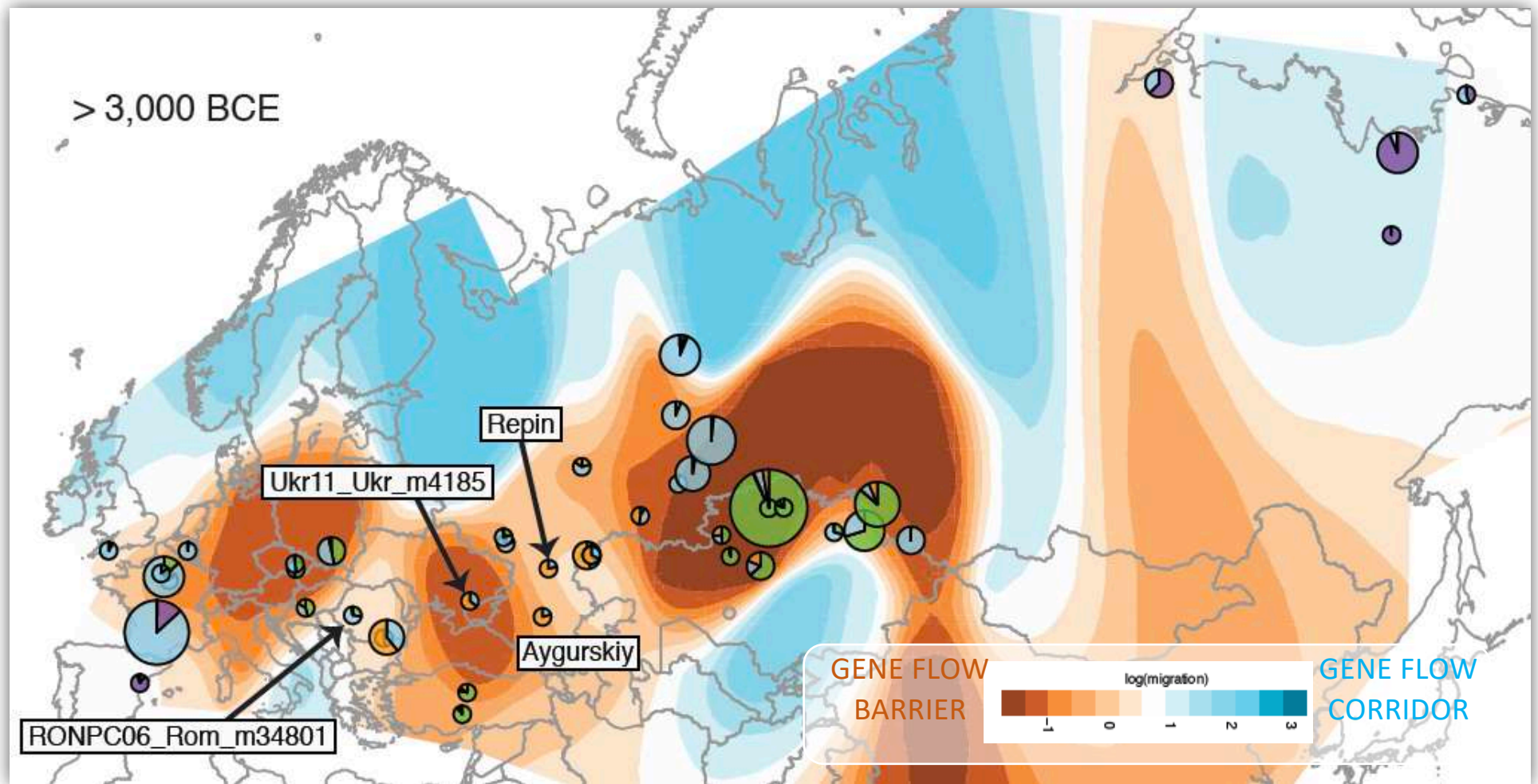
The origins and spread of domestic horses from the Western Eurasian steppes



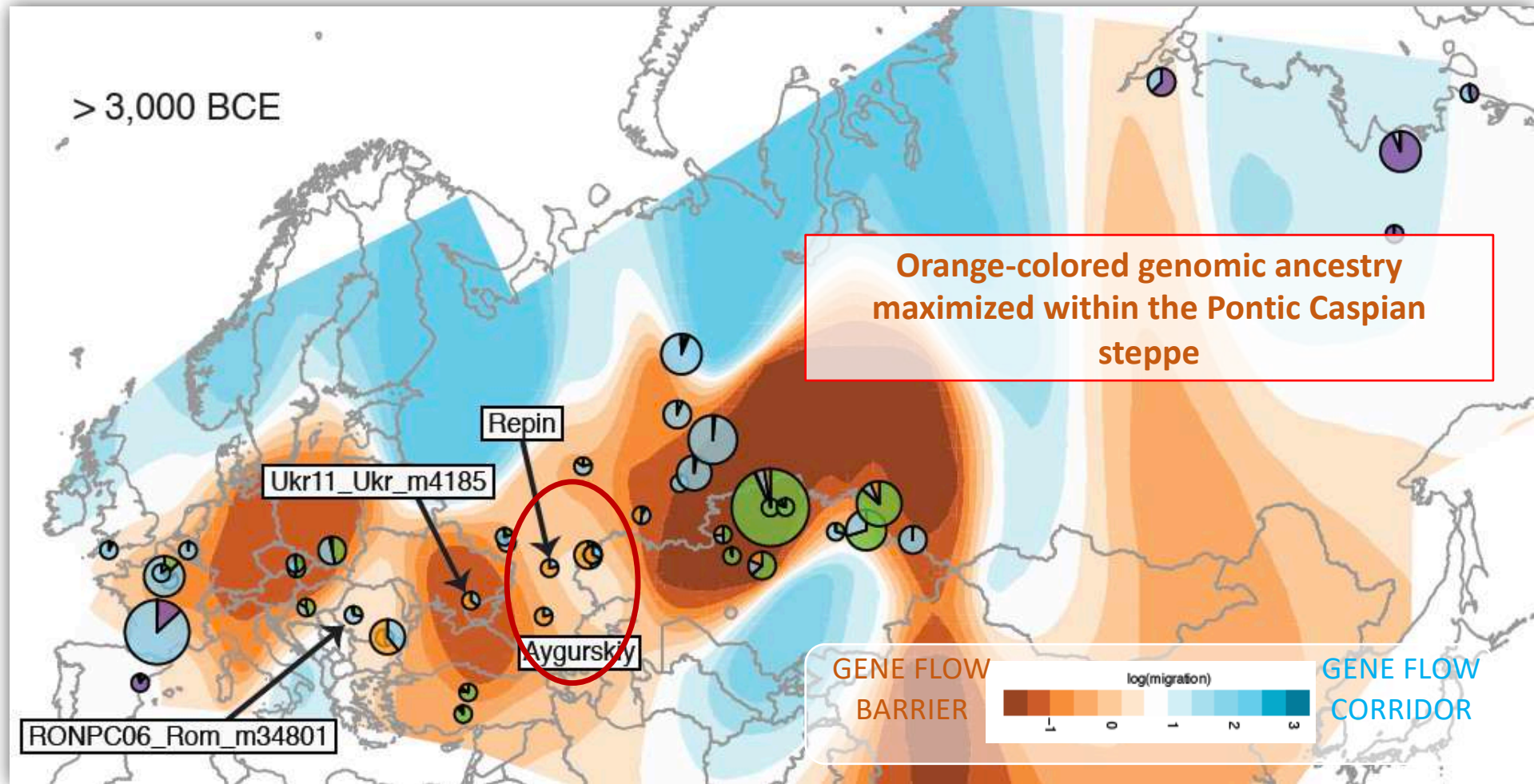
< 4000 KYA: Expansion of DOM2



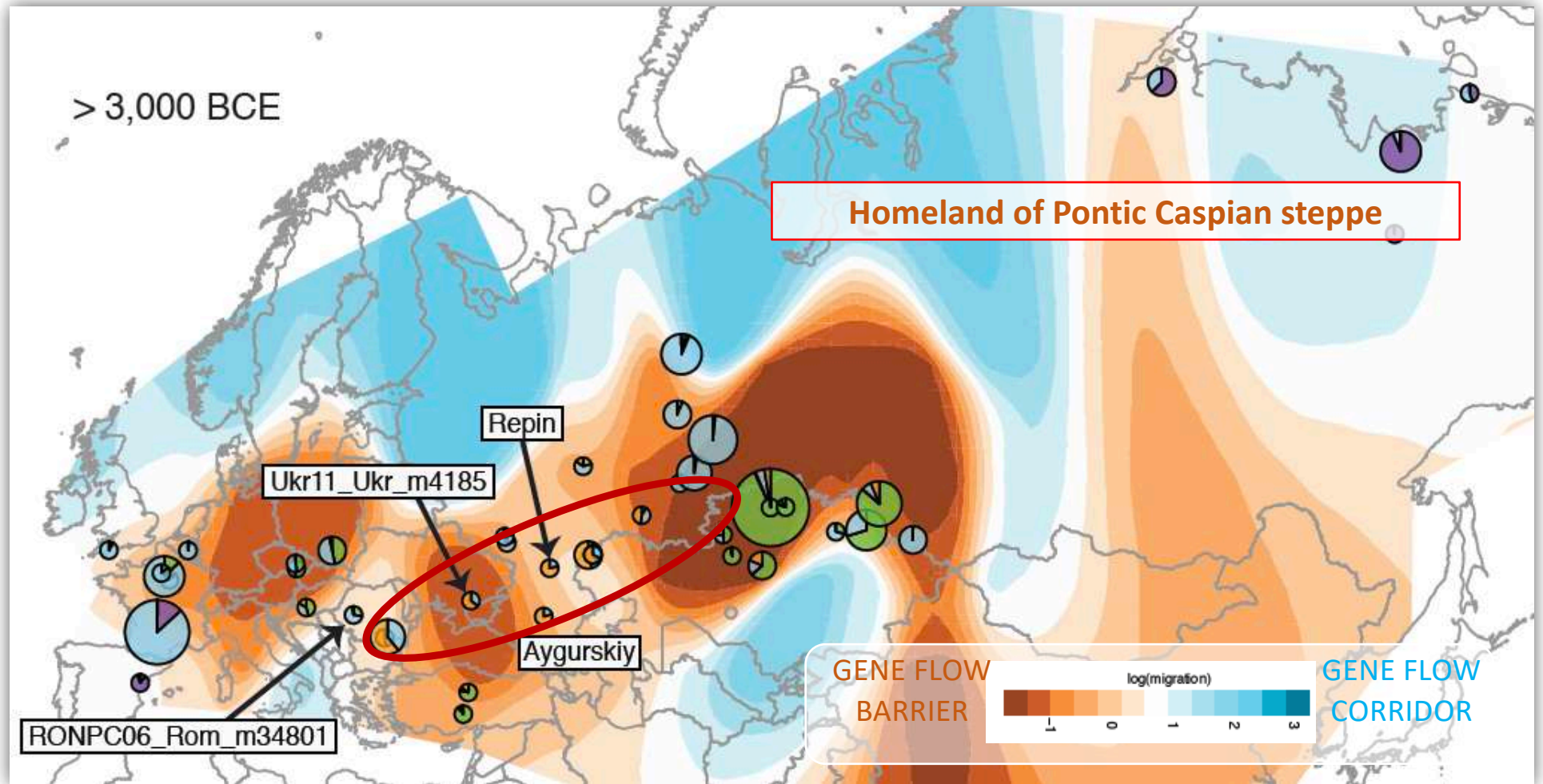
>5000 KYA: DOM2 Homeland



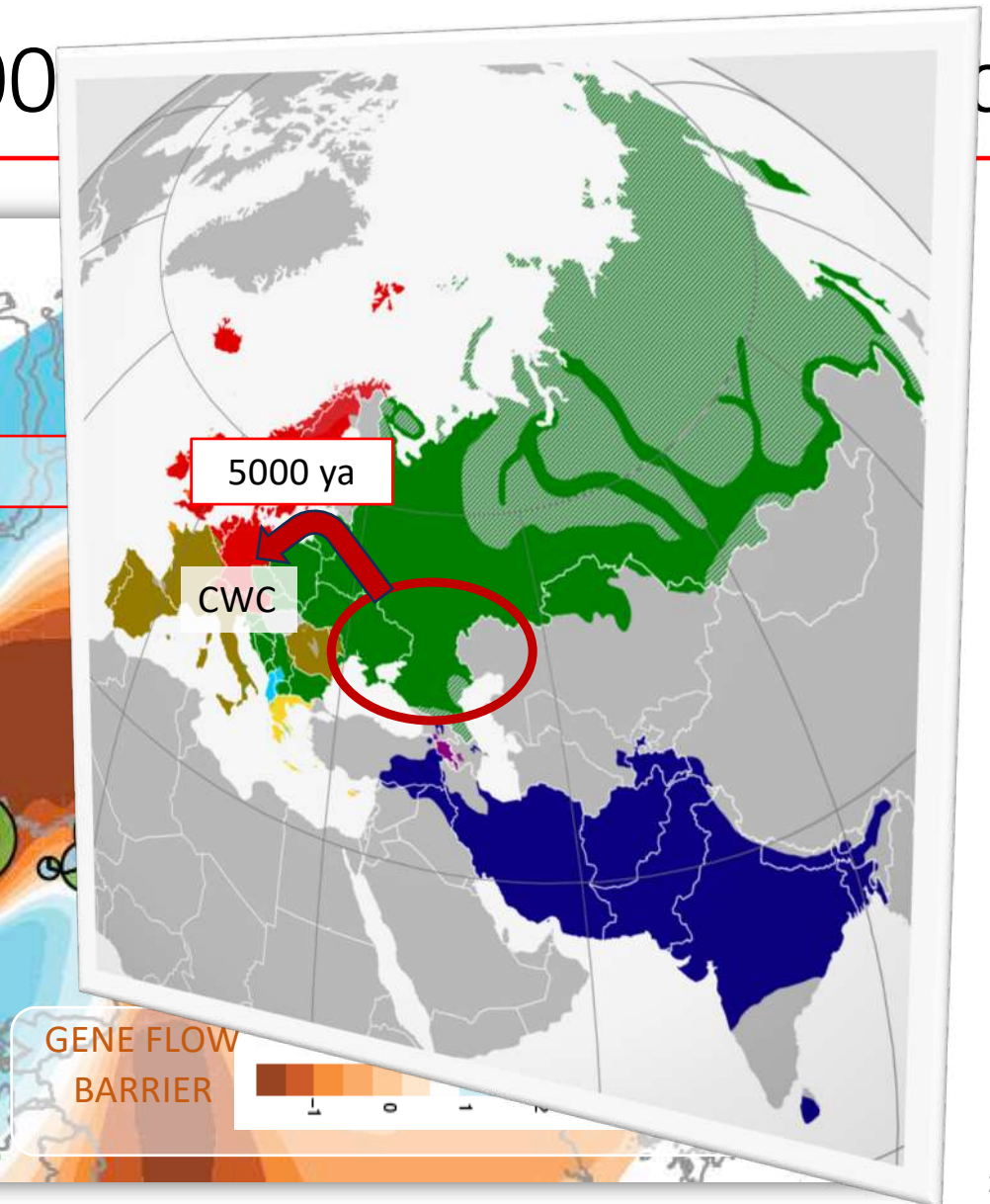
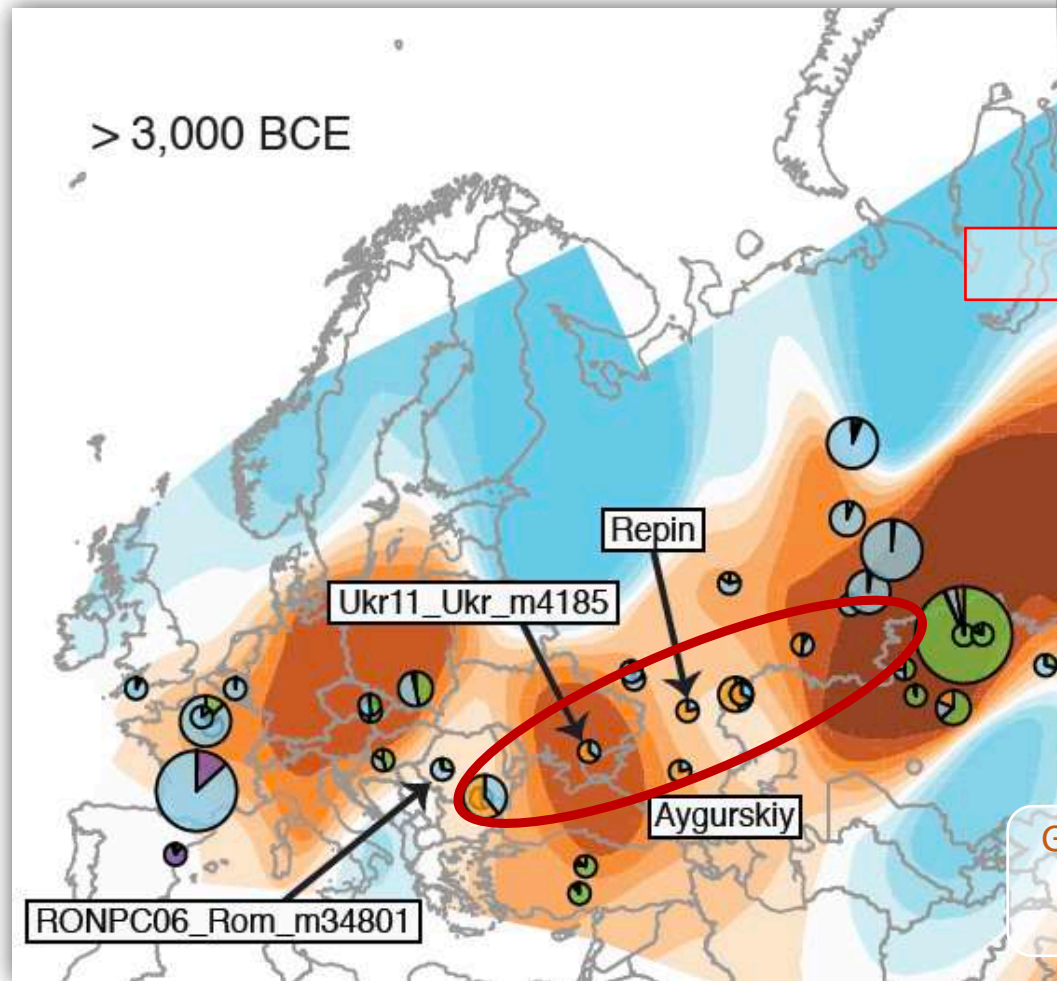
>5000 KYA: DOM2 Homeland



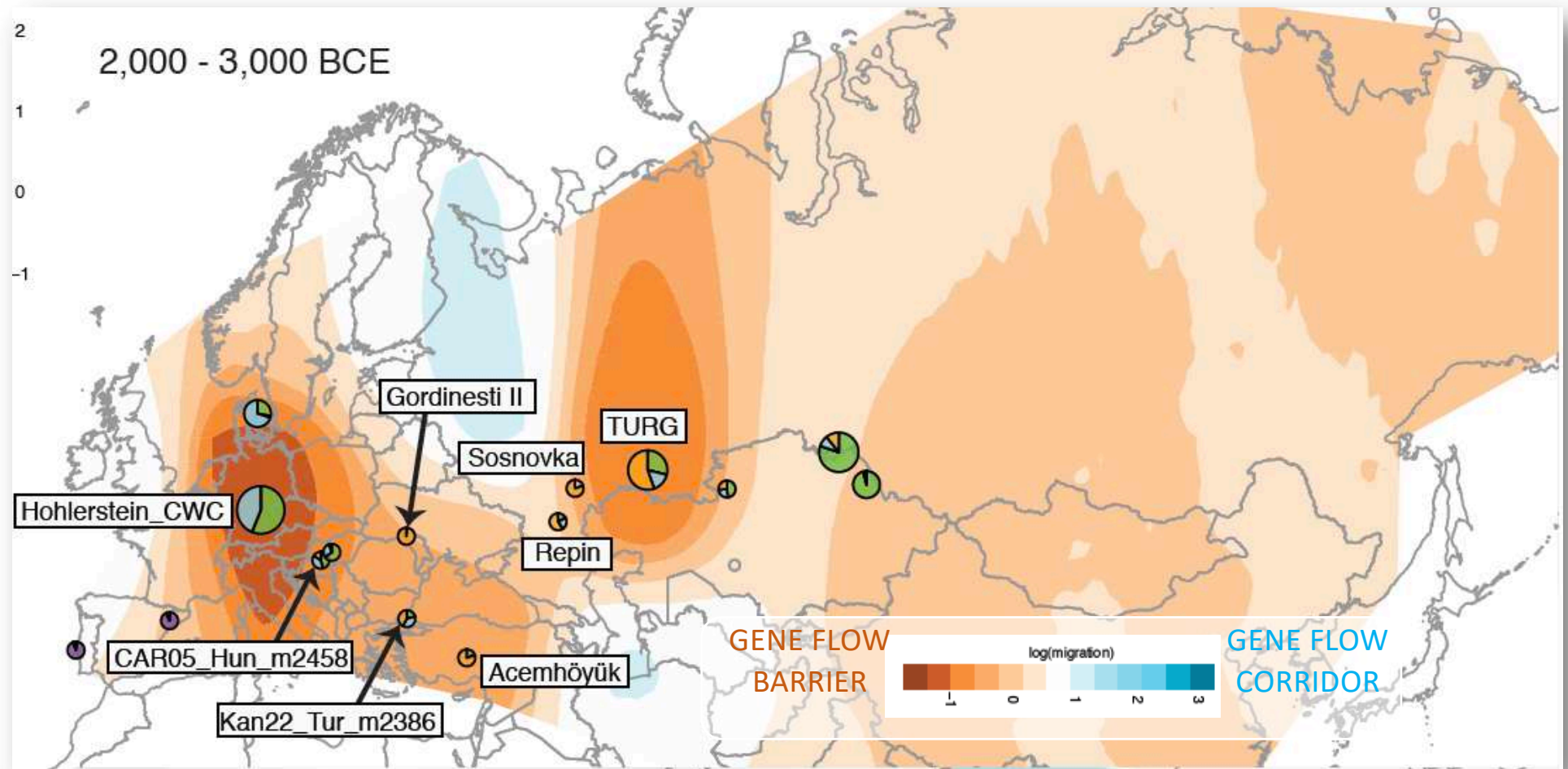
>5000 KYA: DOM2 Homeland



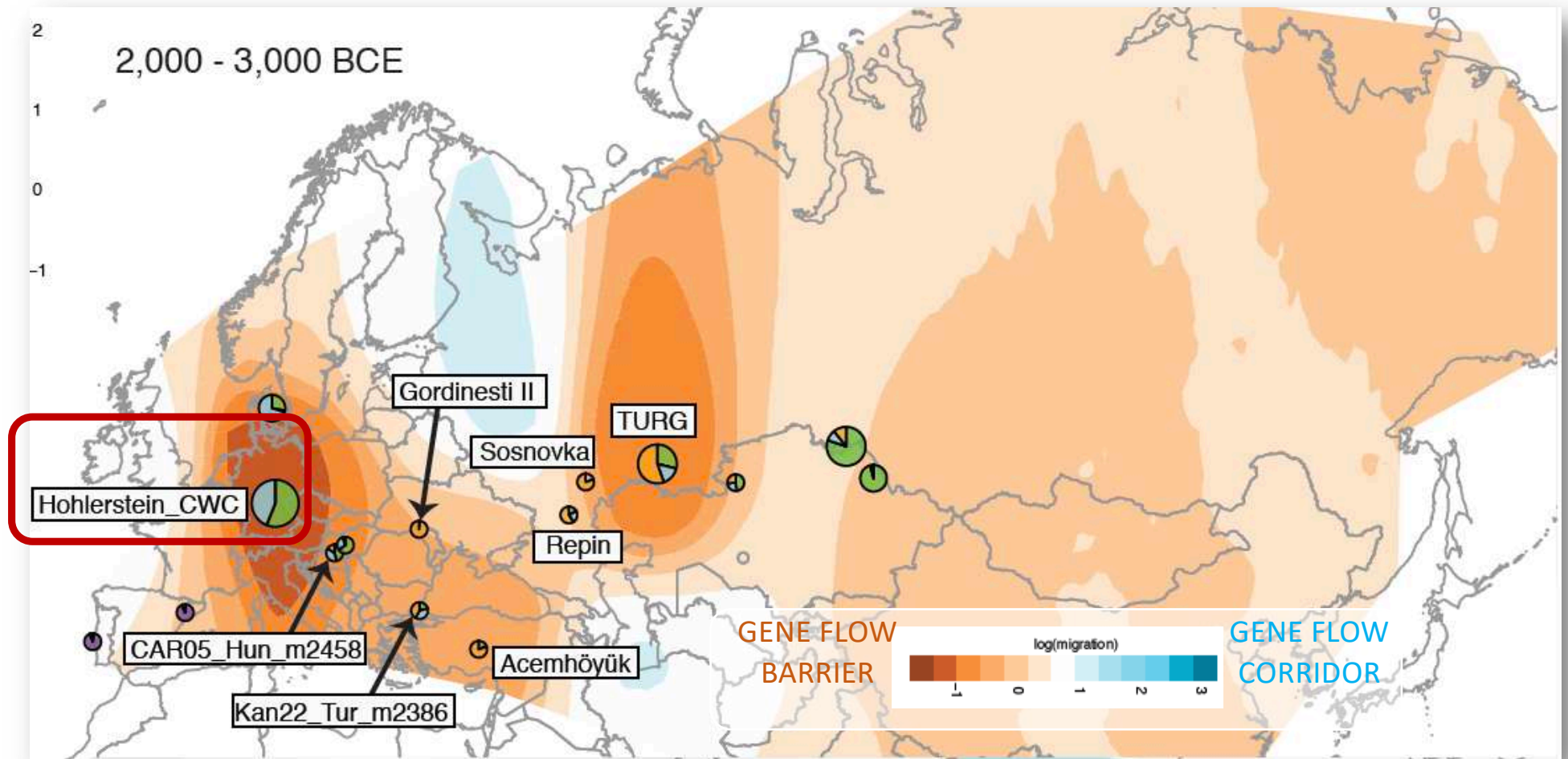
>500



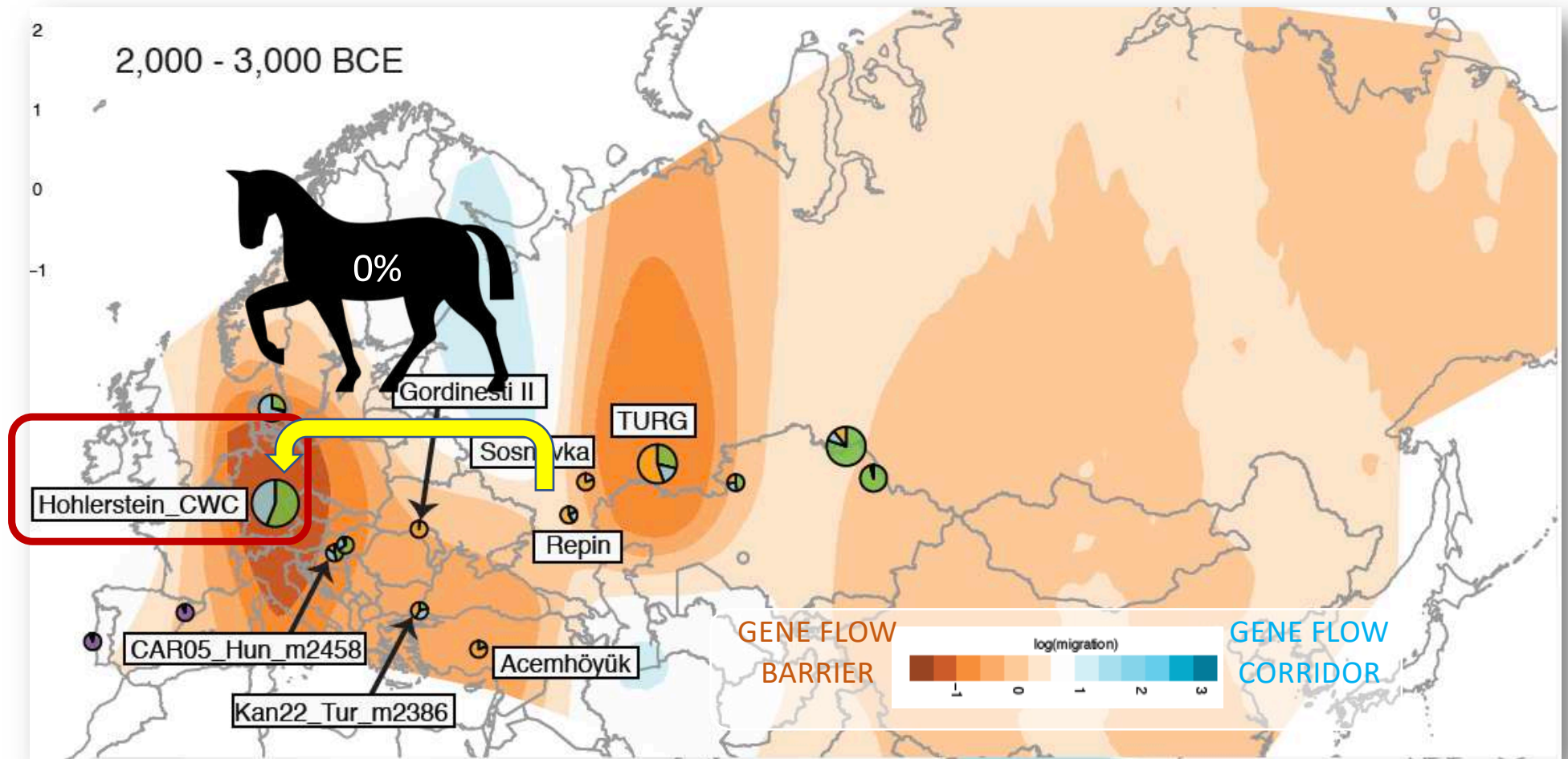
Homeland of DOM2



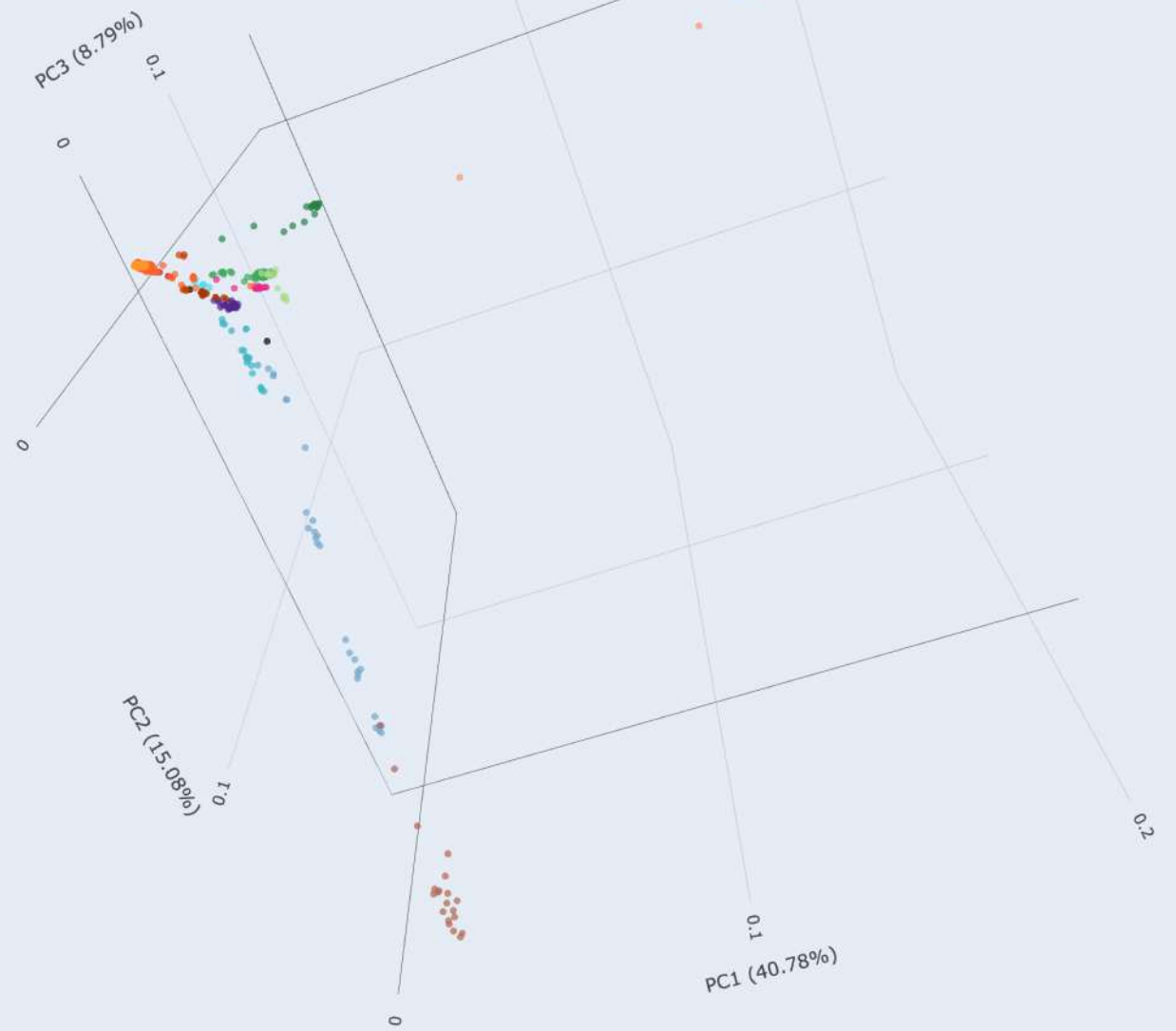
Incongruence: CWC vs. DOM2



Incongruence: CWC vs. DOM2

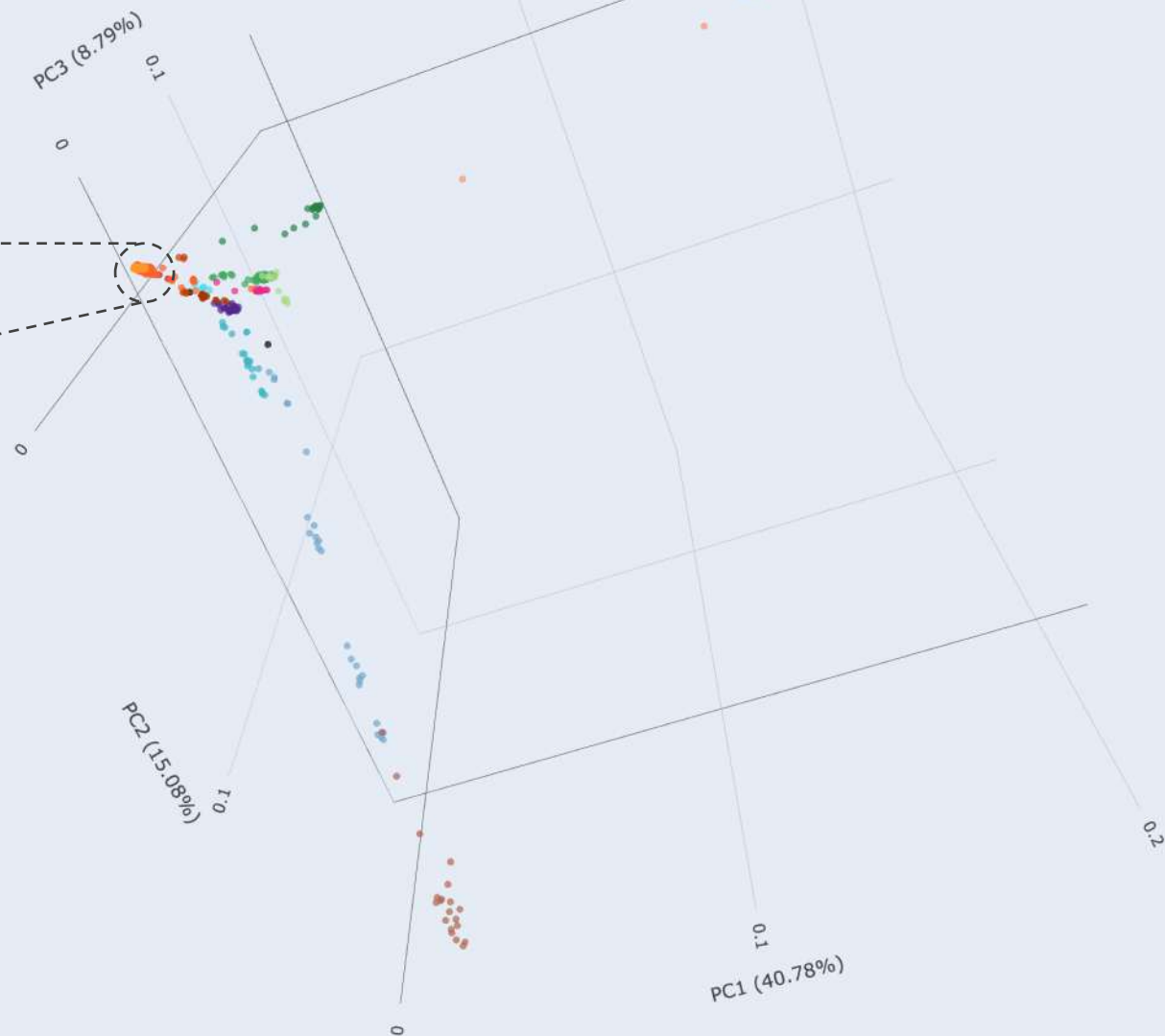
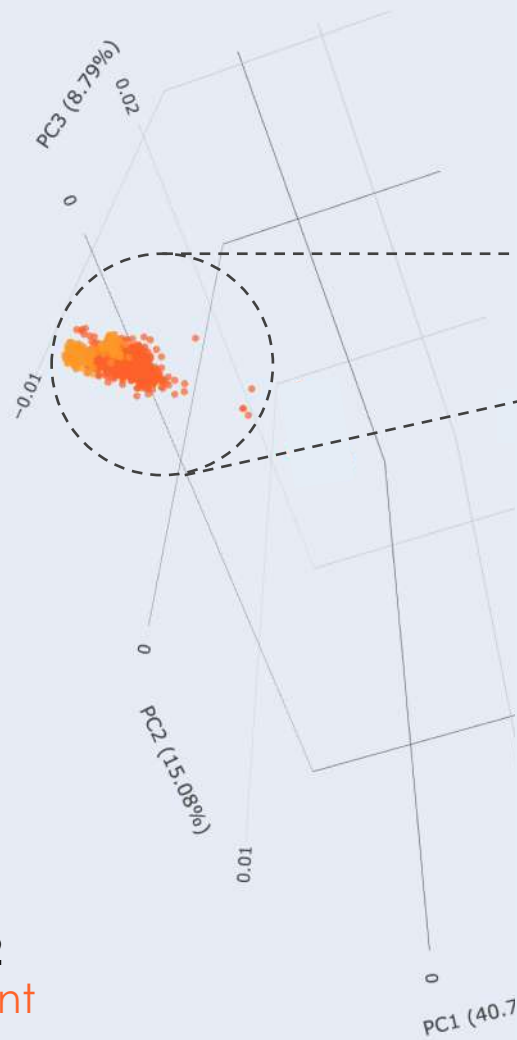


$\geq 4,200$ BP



0-4,200 BP

$\geq 4,200$ BP



DOM2
Ancient
Modern

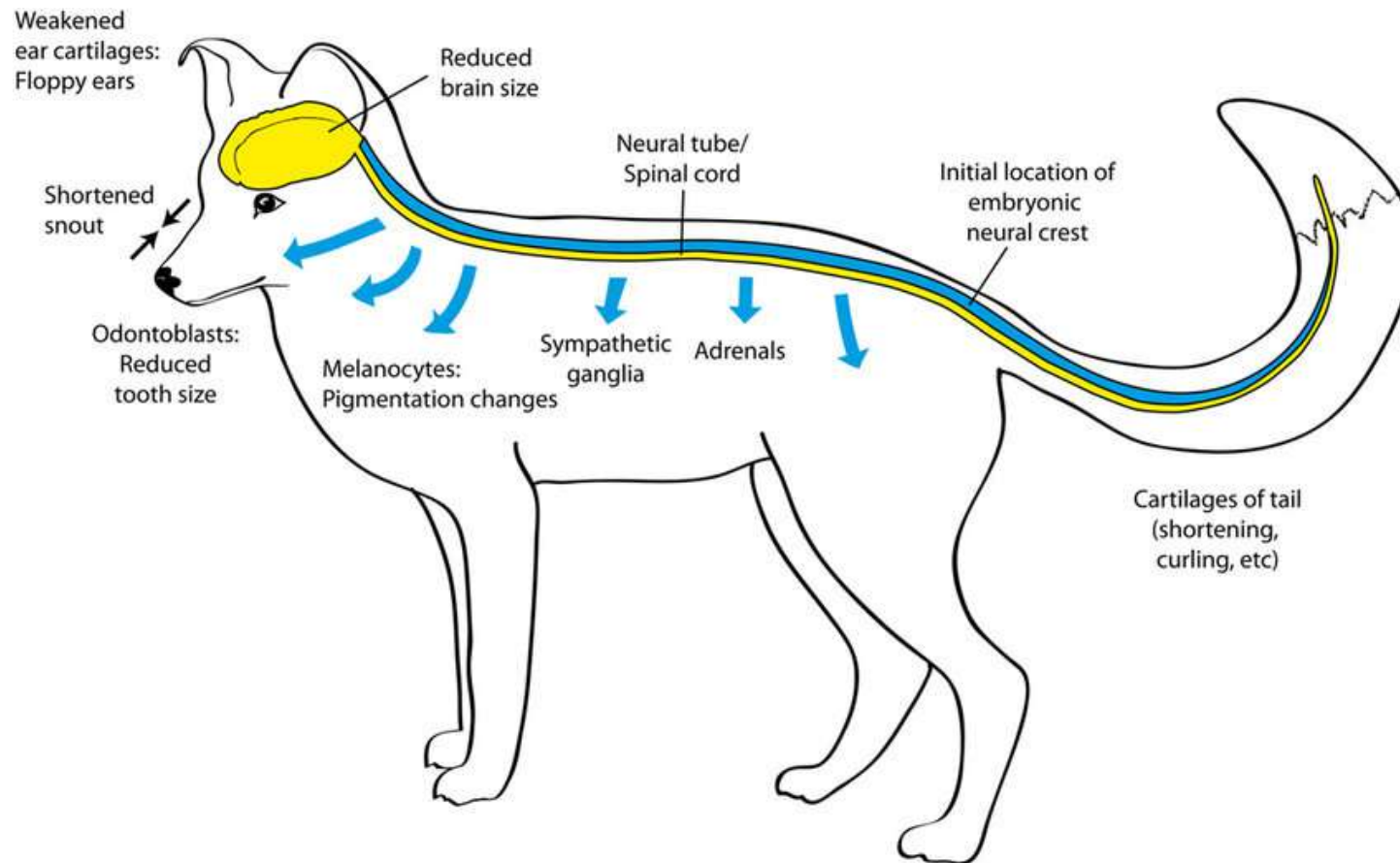
Conclusions

The new era of horse-based mobility started
4,200YA, and **not before**



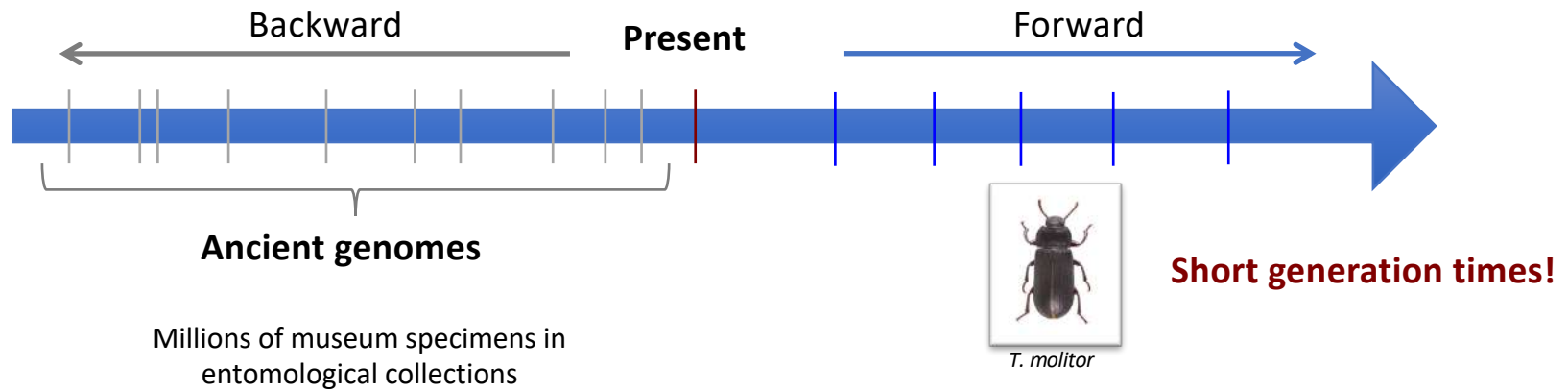
This is something we only can know thanks to ancient DNA

HOW?

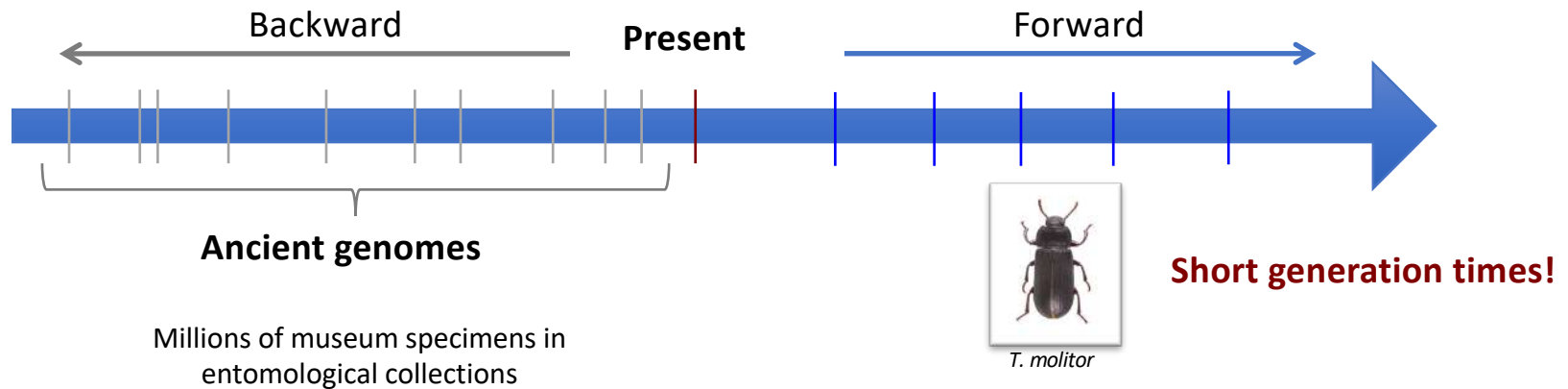


Docility -> Neural crest (neural tube) -> Impact many other phenotypes typical of the domestication syndrome

Edible insect domestication



T. molitor reference genomes



Download ▾

Select columns

7 Genomes

Rows per page 20 ▾

1-7 of 7 < >

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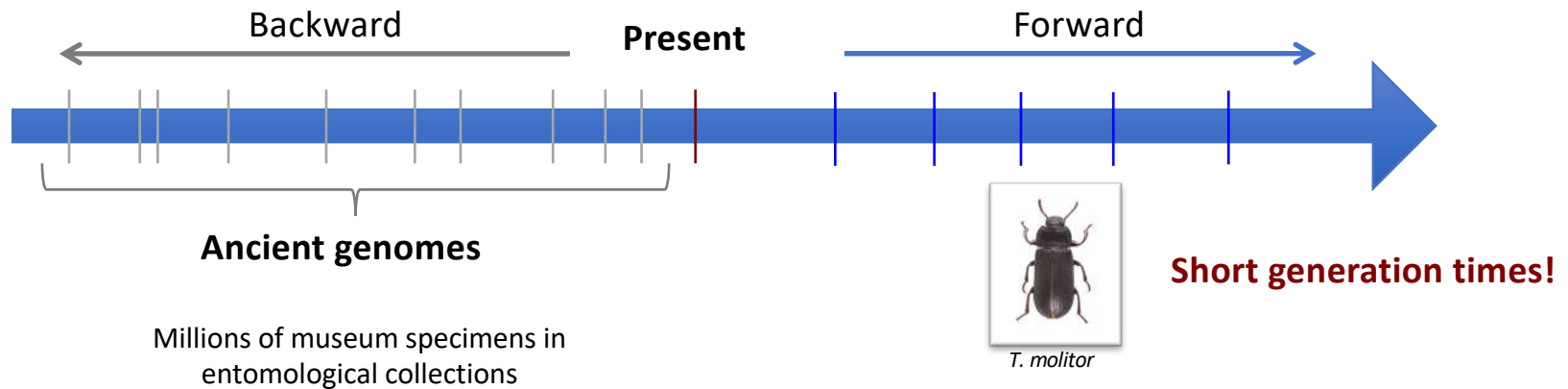
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<input type="checkbox"/>	icTenMoli1.1	GCA_963966145.1		Tenebrio molitor (yellow mealwo...			⋮
<input type="checkbox"/>	Tmo_Genome	GCA_037075425.1		Tenebrio molitor (yellow mealwo...	CGAHR2015 (isolate)		⋮
<input type="checkbox"/>	Tenebrio_molitor_v3	GCA_907166875.3		Tenebrio molitor (yellow mealwo...		Submitter	⋮
<input type="checkbox"/>	ASM2772521v1	GCA_027725215.1		Tenebrio molitor (yellow mealwo...	QUTm001 (isolate)	Submitter	⋮
<input type="checkbox"/>	icTenMoli1.1 alternate haplotype	GCA_963966125.1		Tenebrio molitor (yellow mealwo...			⋮
<input type="checkbox"/>	Tmol_A_ngenome66x_run1.1_13_...	GCA_014282415.3		Tenebrio molitor (yellow mealwo...	Stoneville (strain)	Submitter	⋮

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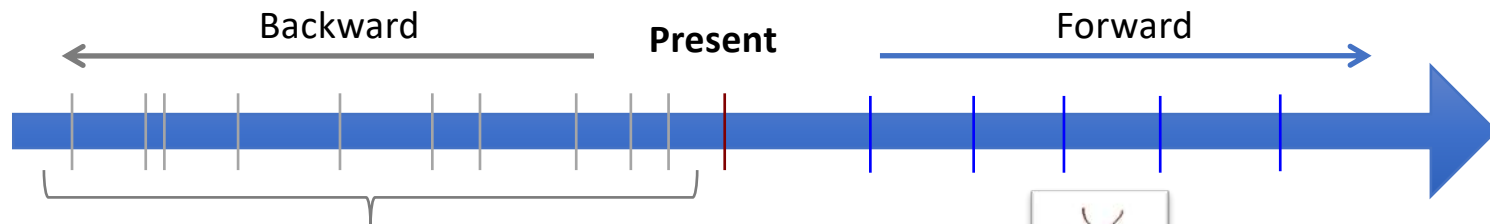
T. molitor reference genomes



Download ▾		Select columns		7 Genomes		Rows per page	20 ▾	1-7 of 7	<	>
<input type="checkbox"/>	Assembly	GenBank	RefSeq	Scientific name	Modifier	Annotation	Action			
<input type="checkbox"/>	icTenMoli1.1		GCF_963966145.1	Tenebrio molitor (yellow mealwo...		NCBI RefSeq	...			
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<input type="checkbox"/>	icTenMoli1.1 alternate haplotype	GCA_963966125.1		Tenebrio molitor (yellow mealwo...			...			
<input type="checkbox"/>	Tmol_A_ngnome66x_run1.1_13...	GCA_014282415.3		Tenebrio molitor (yellow mealwo...	Stoneville (strain)	Submitter	...			
				Rows per page	20 ▾	1-7 of 7	<	>		

200-300Mb

T. molitor reference genomes



Ancient genomes

Millions of museum specimens in entomological collection

Short generation times!



7 Genomes			
Download	Select columns		
<input type="checkbox"/>	Assembly	GenBank	RefSeq
<input type="checkbox"/>	icTenMoli1.1		GCF_963966145.1
<input type="checkbox"/>	icTenMoli1.1	GCA_963966145.1	Tenebrio molitor (yellow mealworm)
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Rows per page 20 1-7 of 7

genes

MDPI

Article

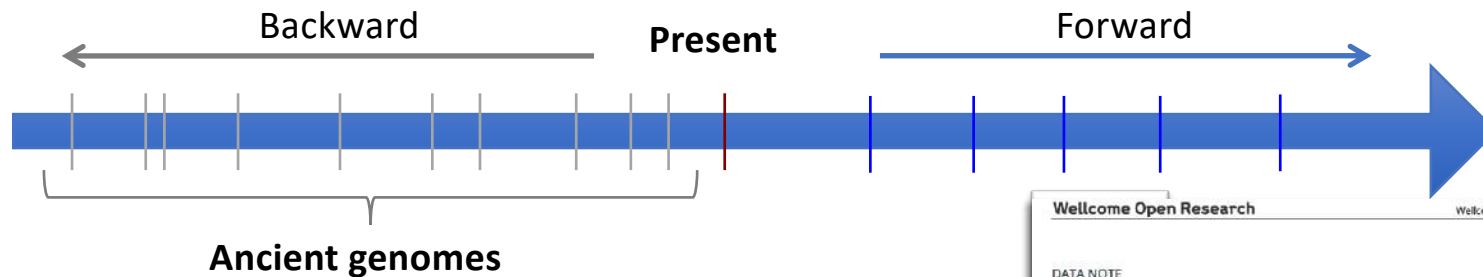
The Genome of the Yellow Mealworm, *Tenebrio molitor*: It's Bigger Than You Think

Brenda Oppert ^{1,*}, Aaron T. Dossey ^{2,3,†}, Fu-Chyun Chu ^{2,†}, Eva Šatović-Vukšić ⁴, Miroslav Plohl ⁴, Timothy P. L. Smith ⁵, Sergey Koren ⁶, Morgan L. Olmstead ^{1,8}, Dewey Leierer ⁷, Gail Ragan ¹ and J. Spencer Johnston ^{8,||}

400 Mb

Real: 750-800 Mb

T. molitor reference genomes



Millions of museum specimens in entomological collections

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<input type="checkbox"/>	Assembly	GenBank	RefSeq	Scientific name	Modifier	Annotation	Action			
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<input type="checkbox"/>	icTenMoli1.1	GCA_963966145.1		<i>Tenebrio molitor</i> (yellow mealwo...			...			
<input type="checkbox"/>	Tmo_Genome	GCA_037075425.1		<i>Tenebrio molitor</i> (yellow mealwo...	CGAHR2015 (isolate)		...			
<input type="checkbox"/>	<i>Tenebrio molitor</i> _v3	GCA_907166875.3		<i>Tenebrio molitor</i> (yellow mealwo...		Submitter	...			
<input type="checkbox"/>	ASM2772521v1	GCA_027725215.1		<i>Tenebrio molitor</i> (yellow mealwo...	QUTm001 (isolate)	Submitter	...			
<input type="checkbox"/>	icTenMoli1.1 alternate haplotype	GCA_963966125.1		<i>Tenebrio molitor</i> (yellow mealwo...			...			
<input type="checkbox"/>	Tmol_A_ngenome66x_run1.1_13...	GCA_014282415.3		<i>Tenebrio molitor</i> (yellow mealwo...	Stoneville (strain)	Submitter	...			
							Rows per page	20 ▾	1-7 of 7	< >

Wellcome Open Research

Wellcome Open Research 2024, 9:459 Last updated: 04 DEC 2024

[Check for updates](#)

DATA NOTE

The genome sequence of the yellow mealworm beetle, *Tenebrio molitor* Linnaeus, 1758

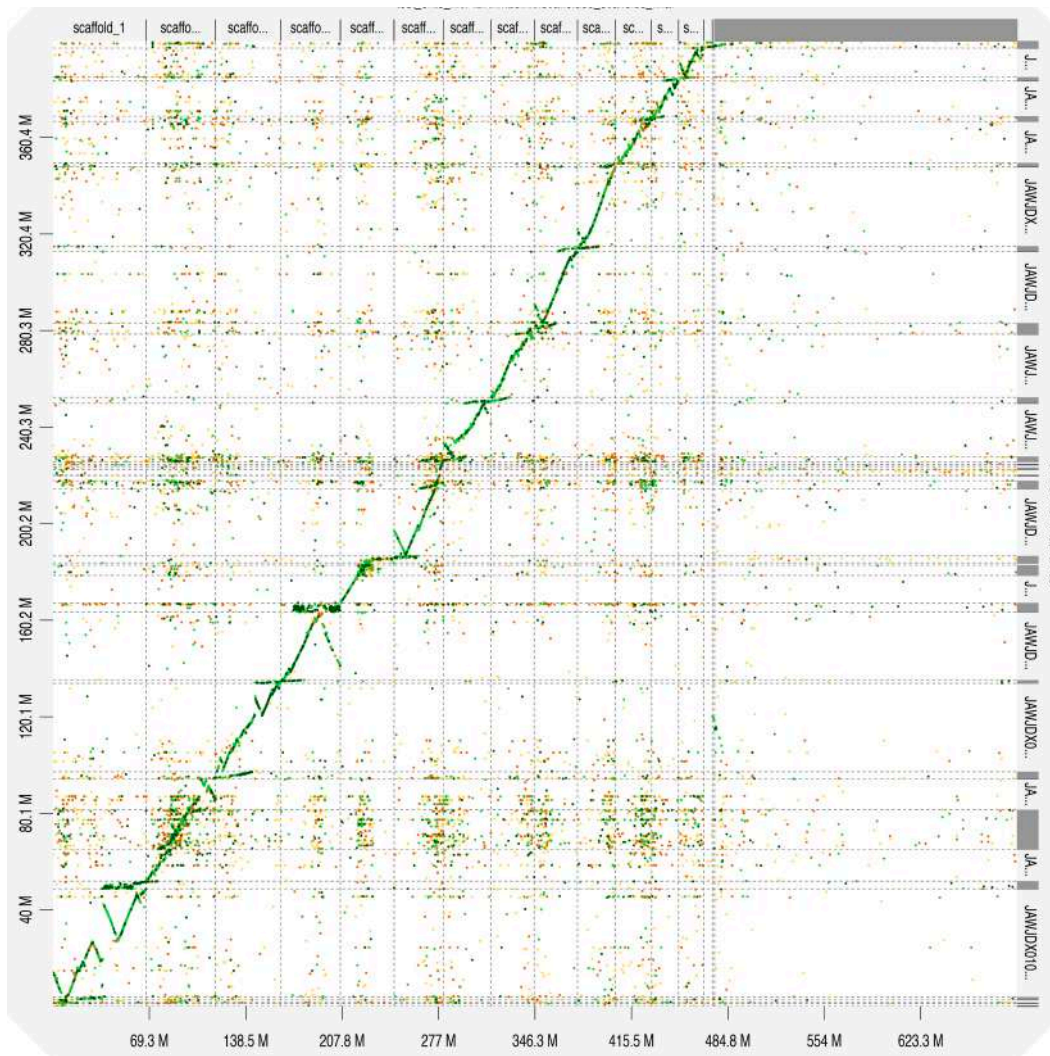
[version 1; peer review: 2 approved]

Darren Mann¹, Liam M. Crowley^{1,2}, Nilo Merino Recalde^{1,2}, University of Oxford and Wytham Woods Genome Acquisition Lab, Darwin Tree of Life Barcoding collective, Wellcome Sanger Institute Tree of Life Management, Samples and Laboratory team, Wellcome Sanger Institute Scientific Operations: Sequencing Operations, Wellcome Sanger Institute Tree of Life Core Informatics team, Tree of Life Core Informatics collective, Darwin Tree of Life Consortium

¹Oxford University Museum of Natural History, Oxford, England, UK
²University of Oxford, Oxford, England, UK

277 Mb

Our assembly (485-690Mb?)

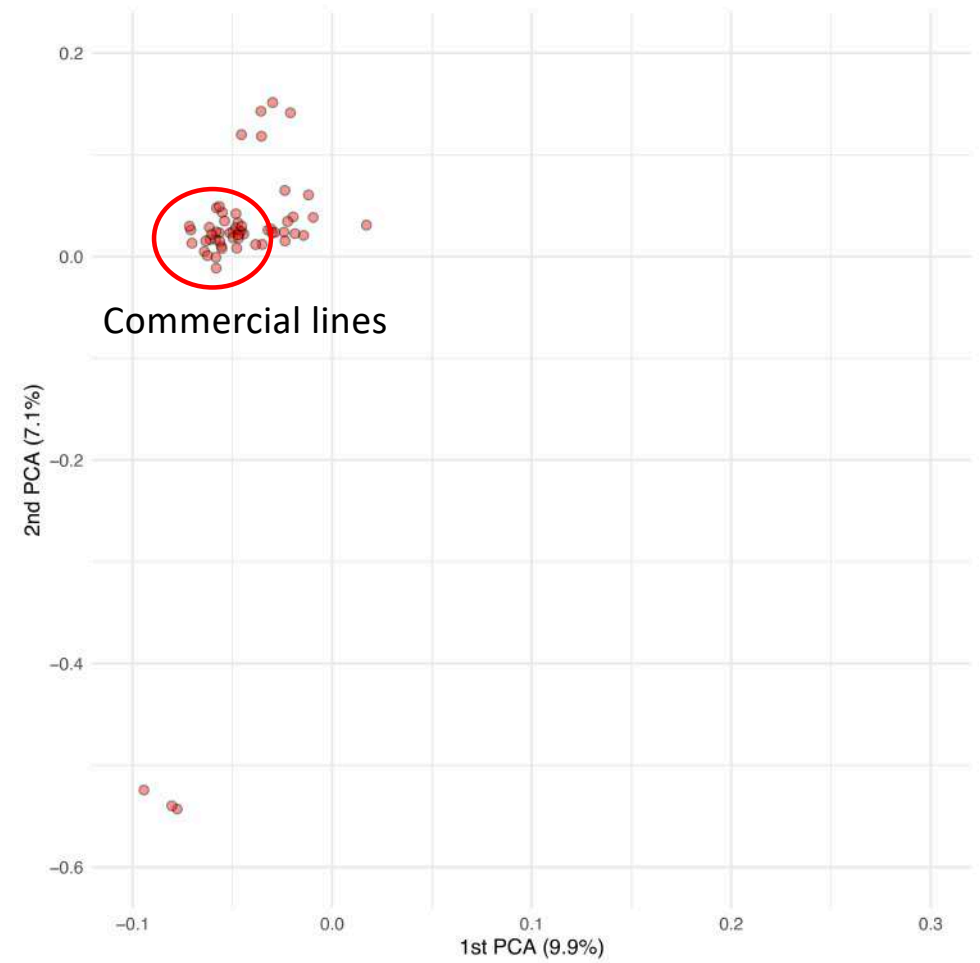


Old assembly (400Mb)

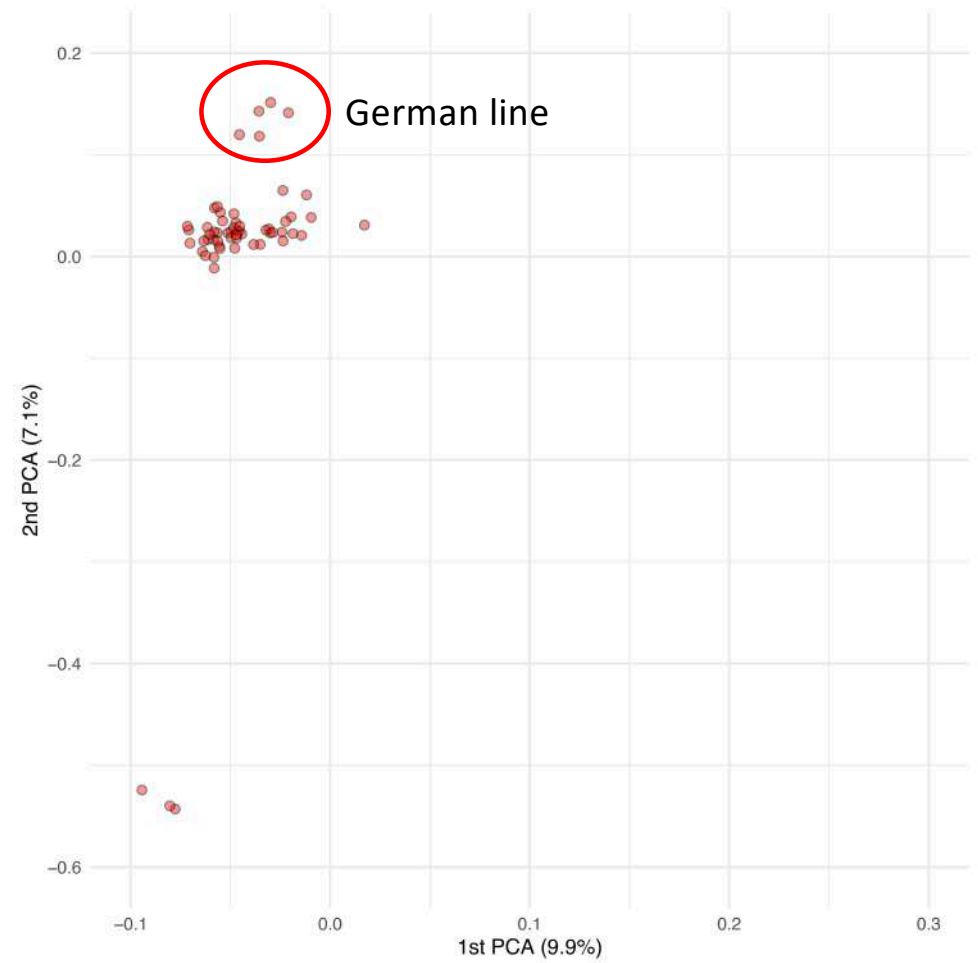
N50 : 36 Mb
690 Mb (or 485 Mb?)

we can and we will do better

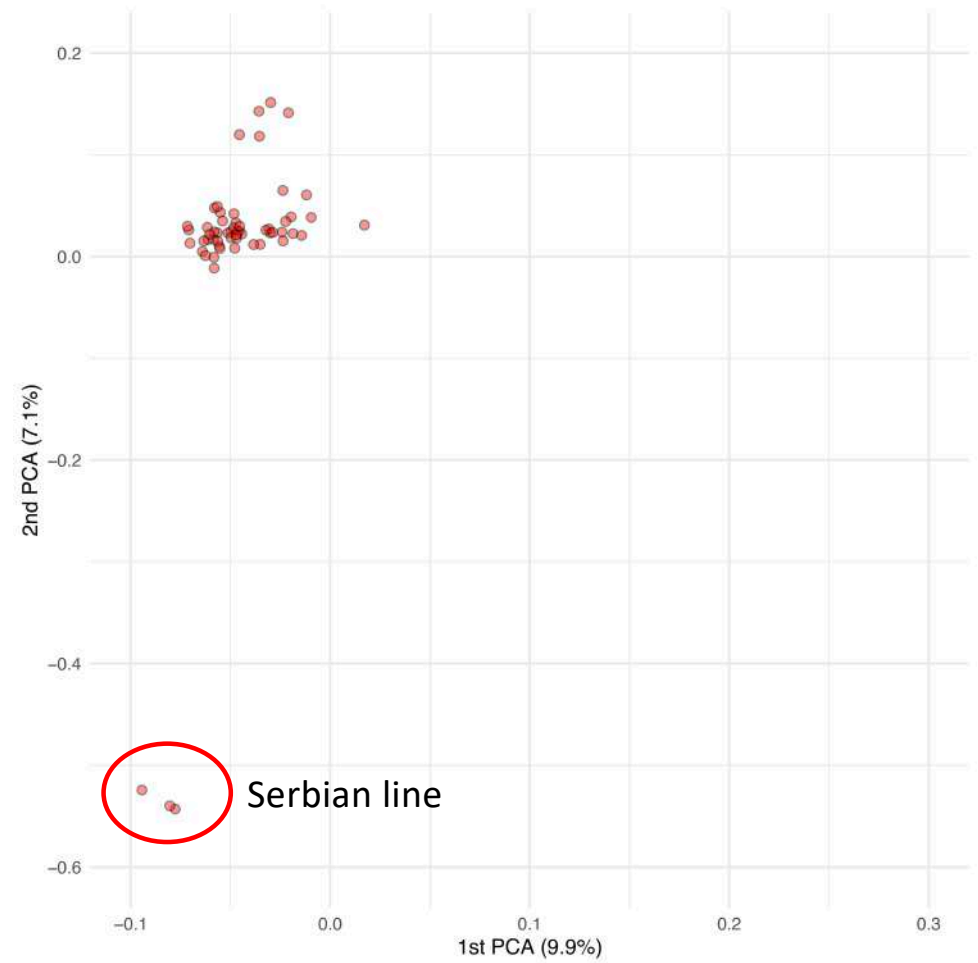
Modern population diversity



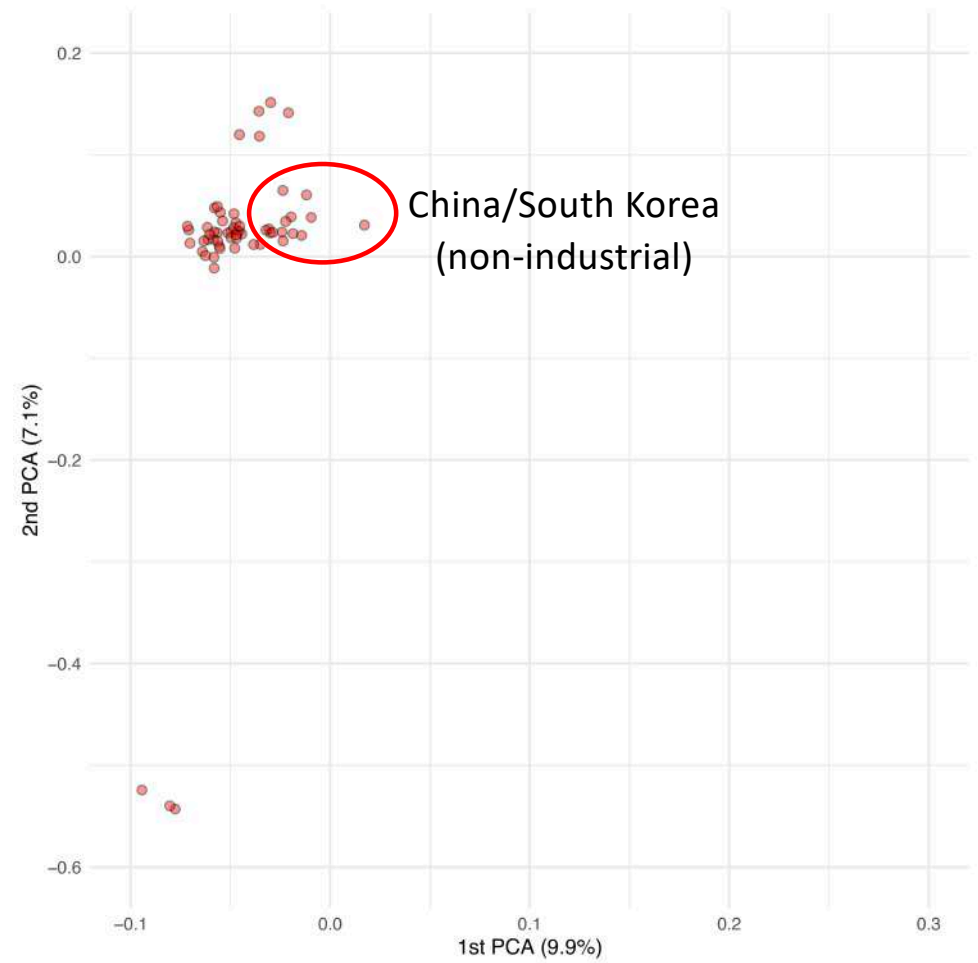
Edible insect domestication



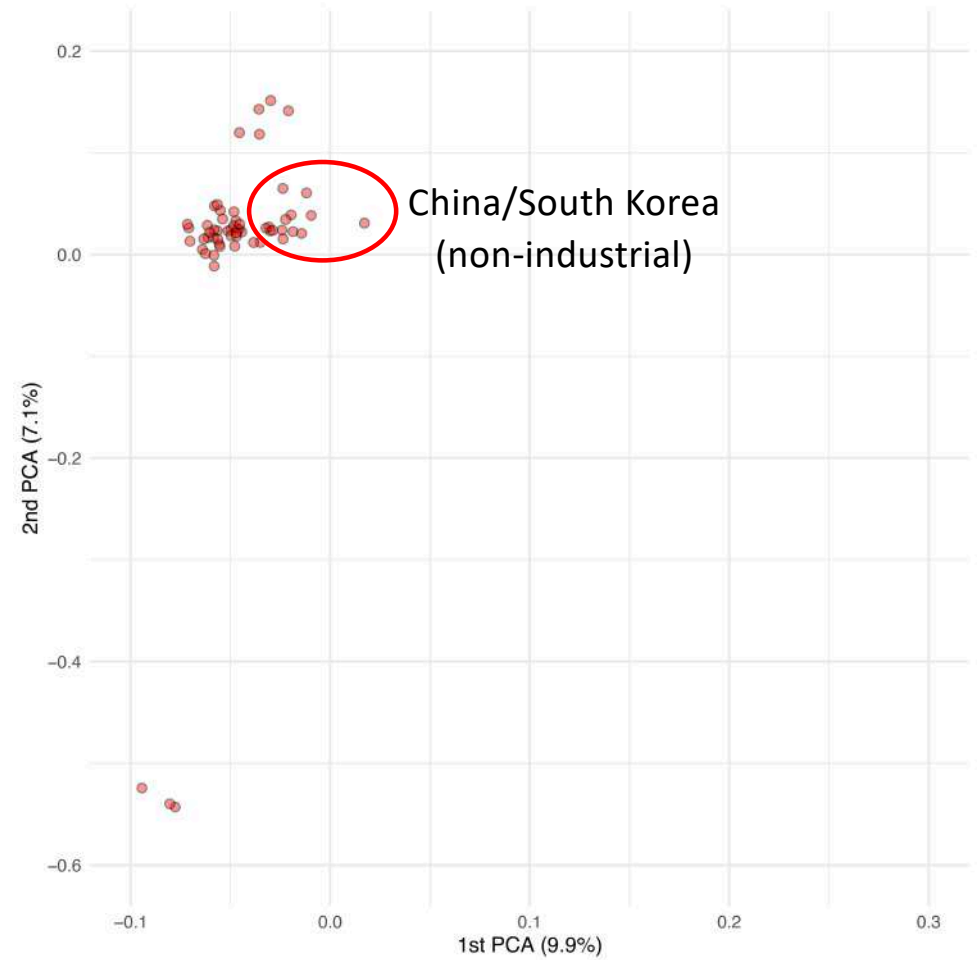
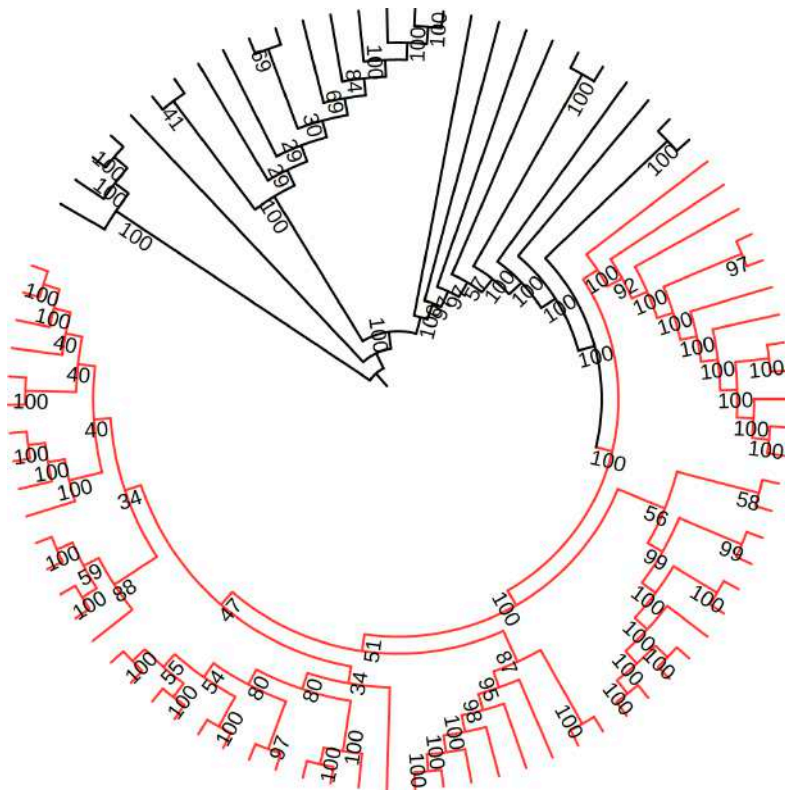
Modern population diversity



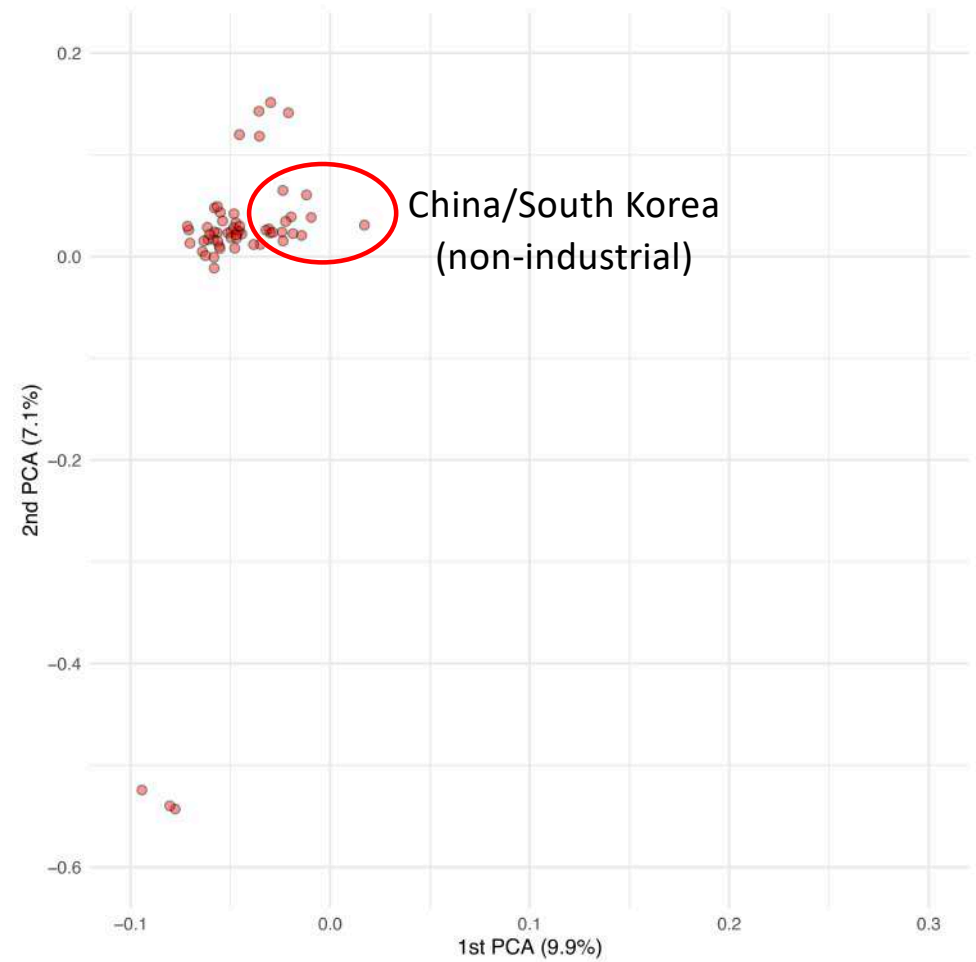
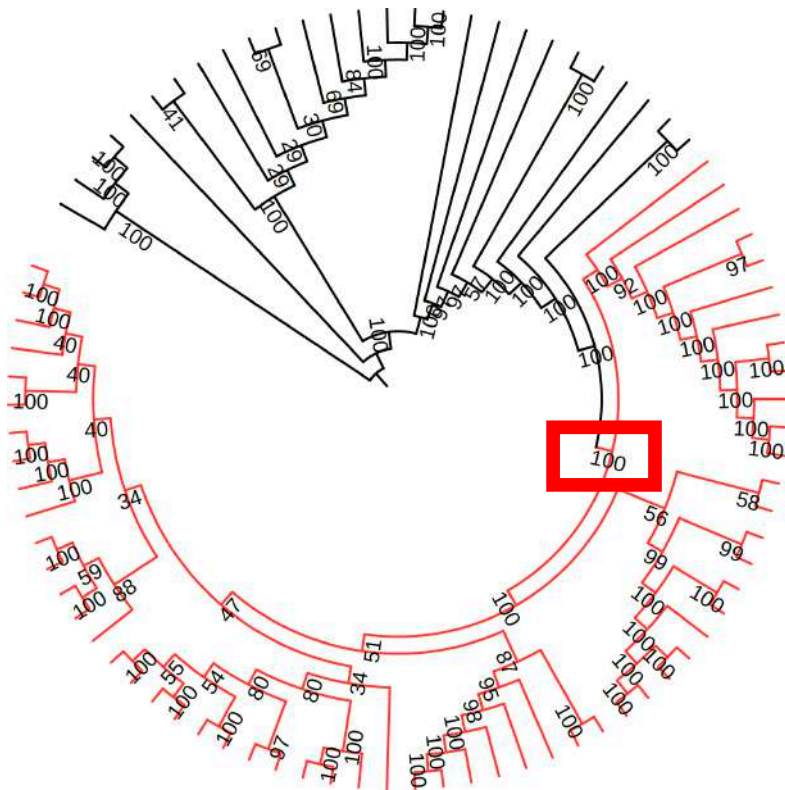
Modern population diversity



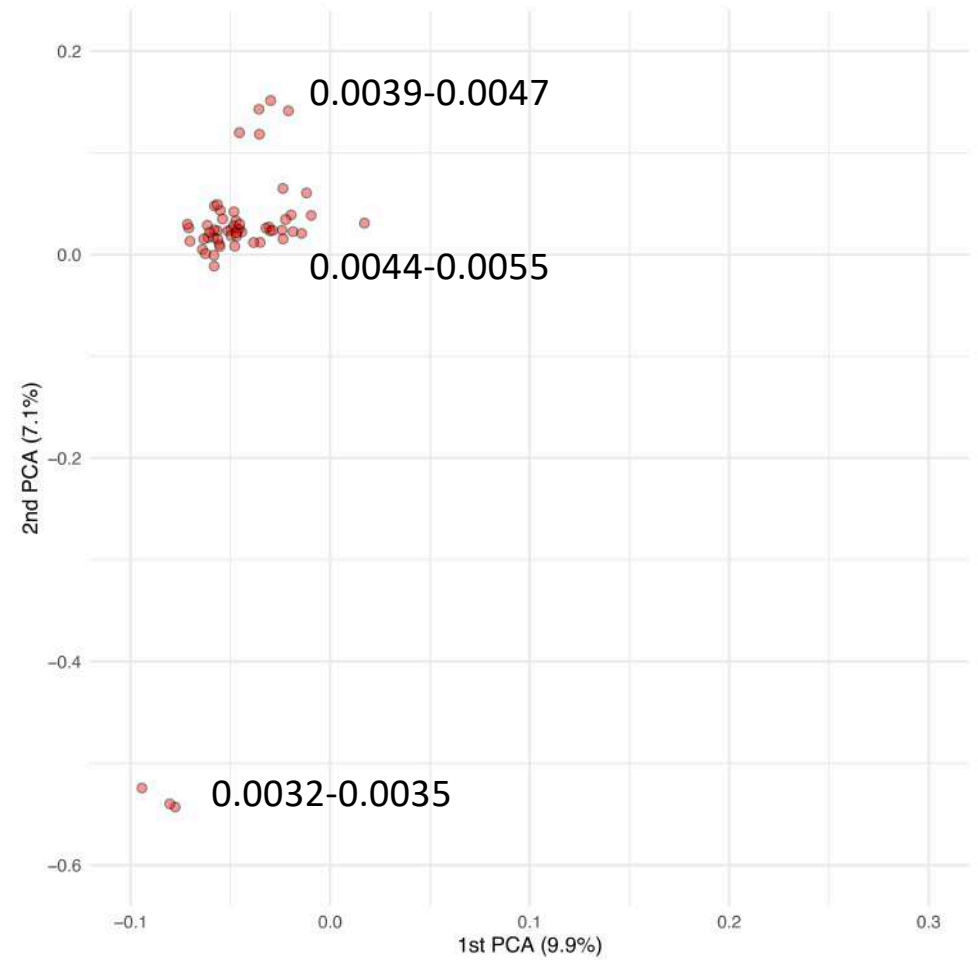
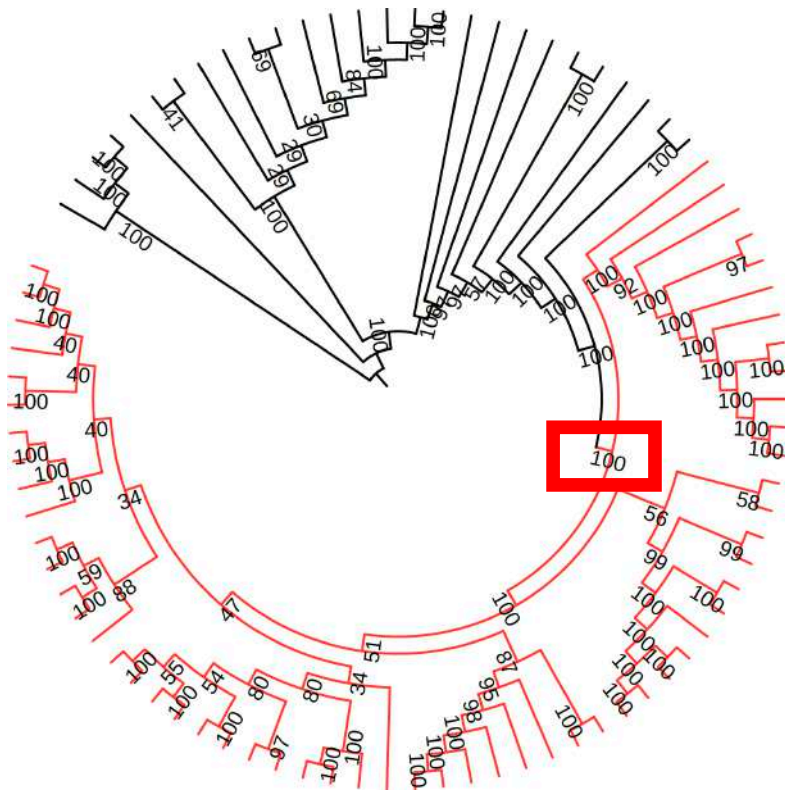
Modern population diversity



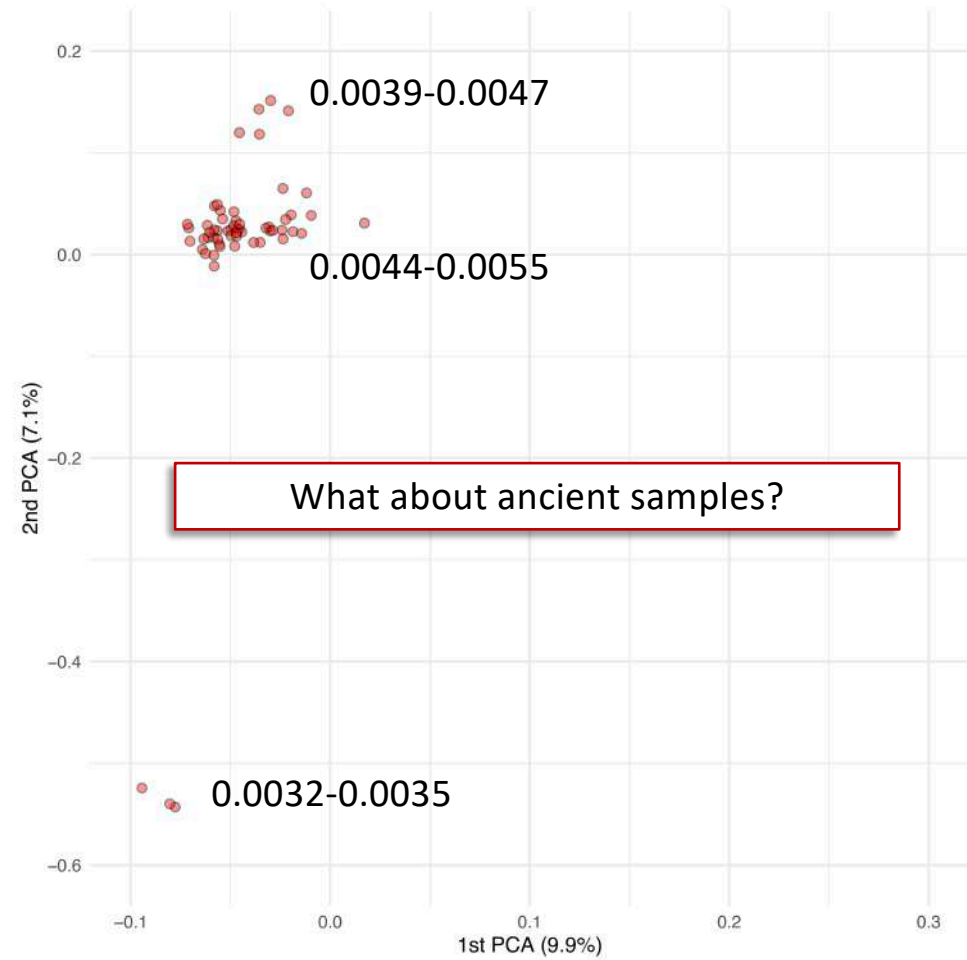
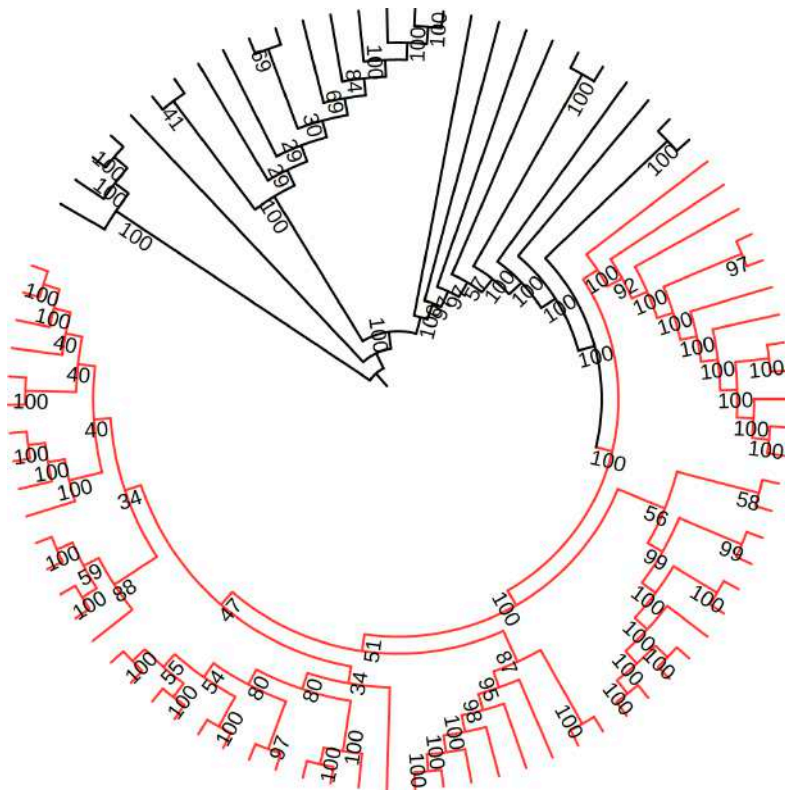
Modern population diversity



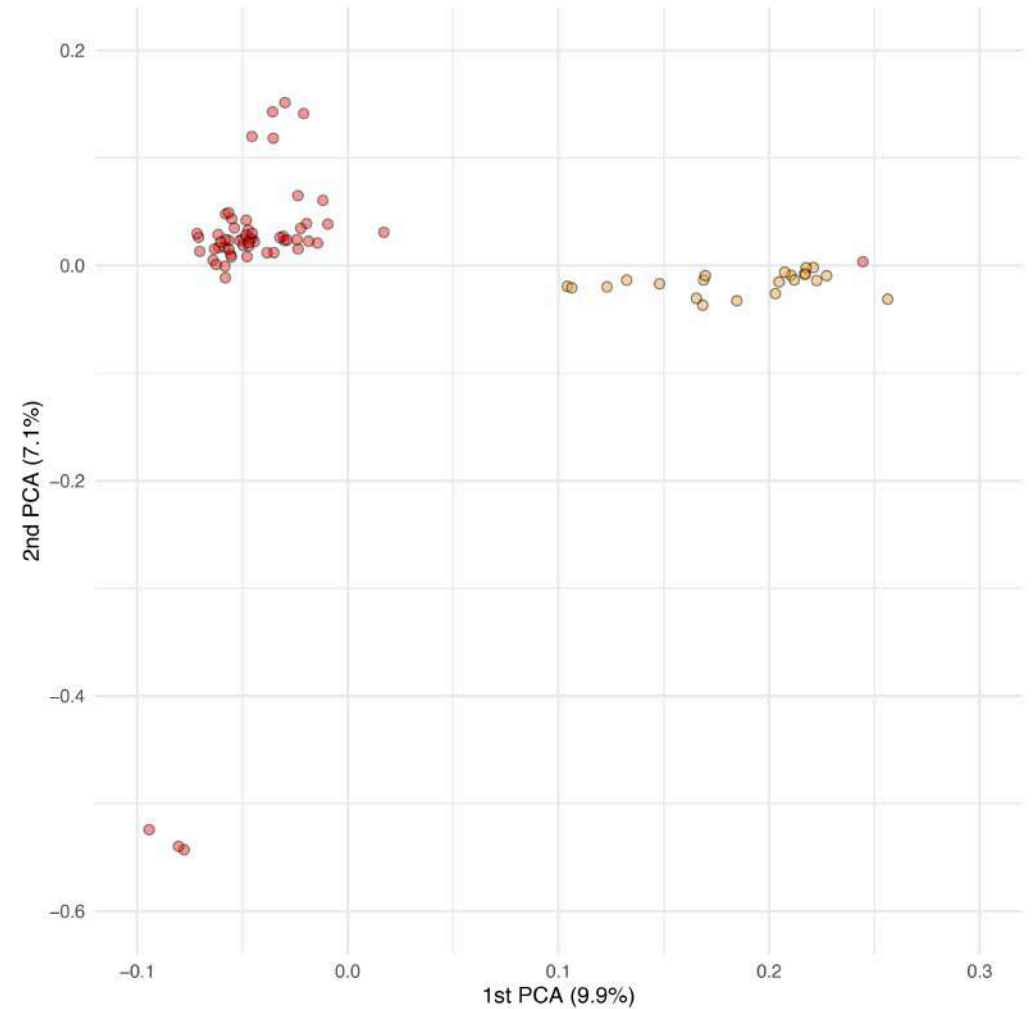
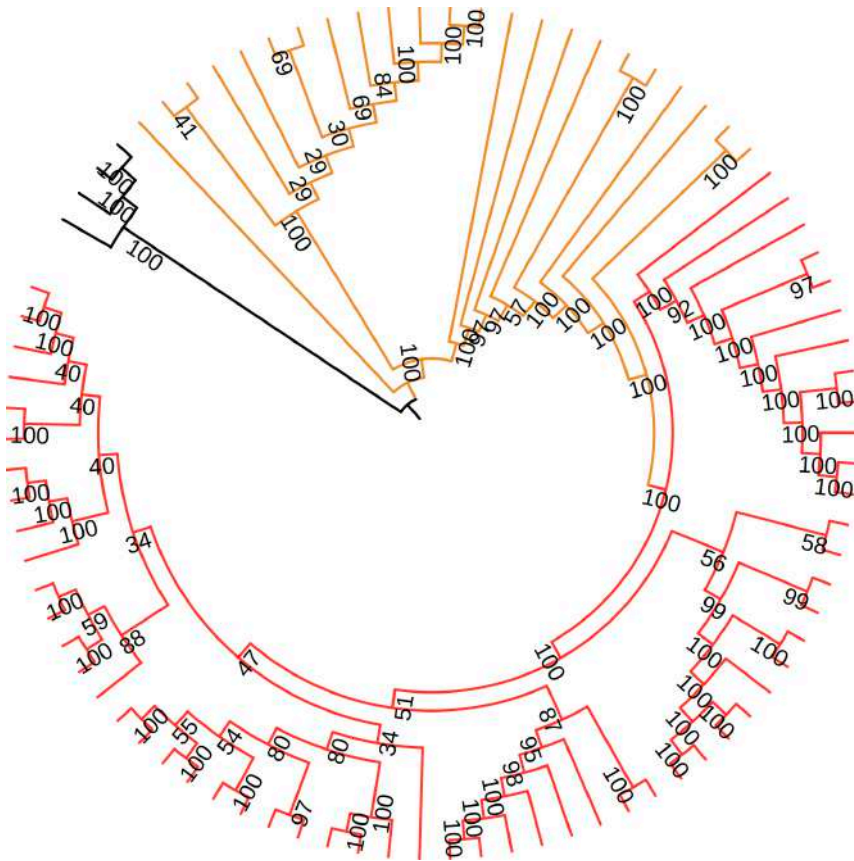
Modern population diversity



Modern population diversity



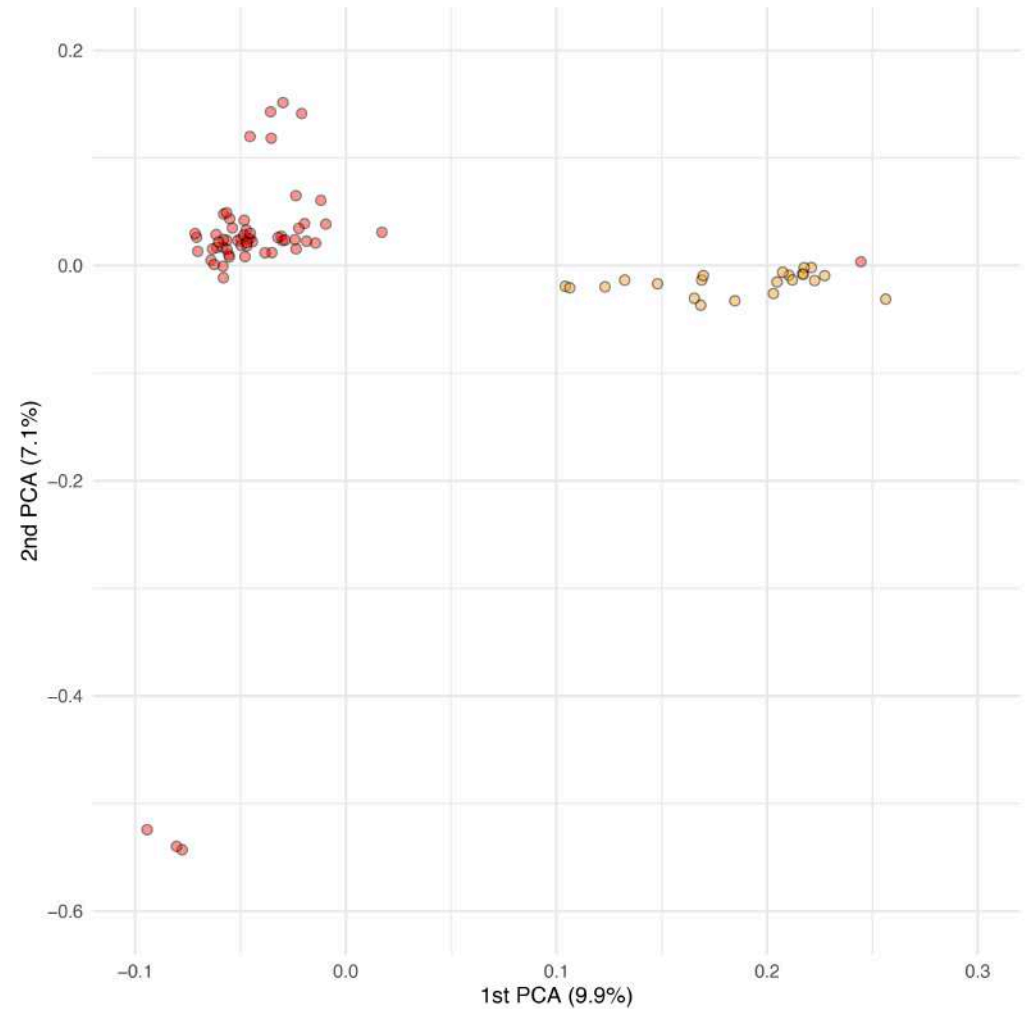
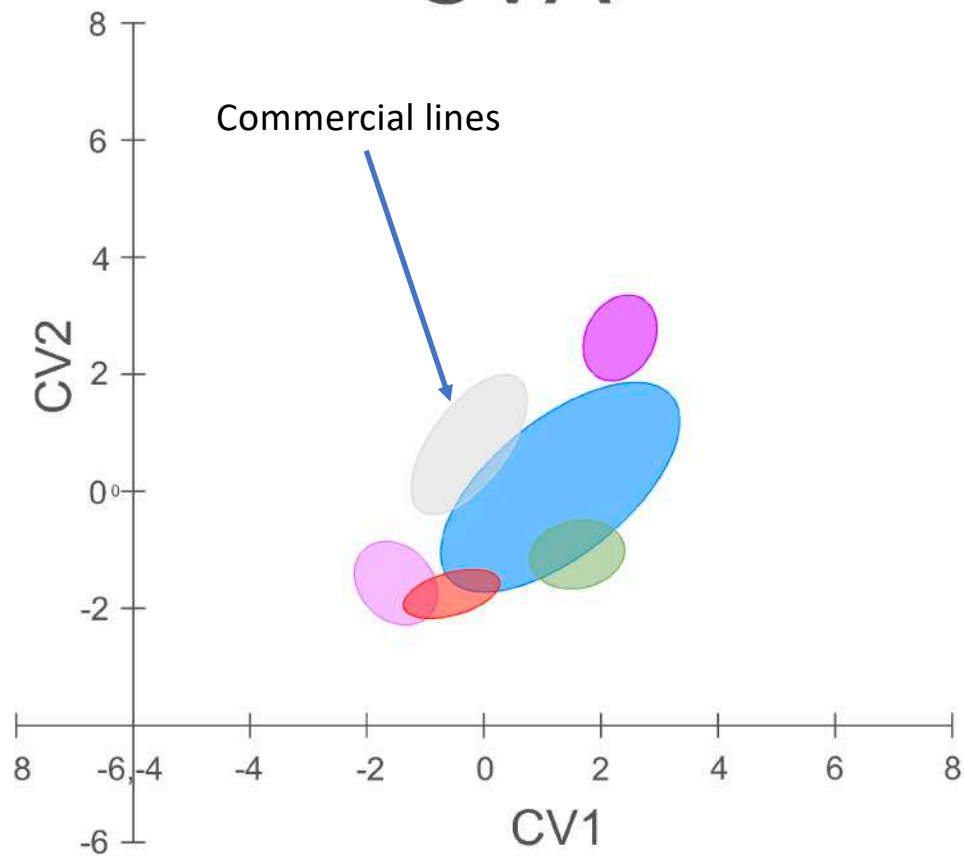
Modern & ancient population diversity





Modern & ancient population diversity

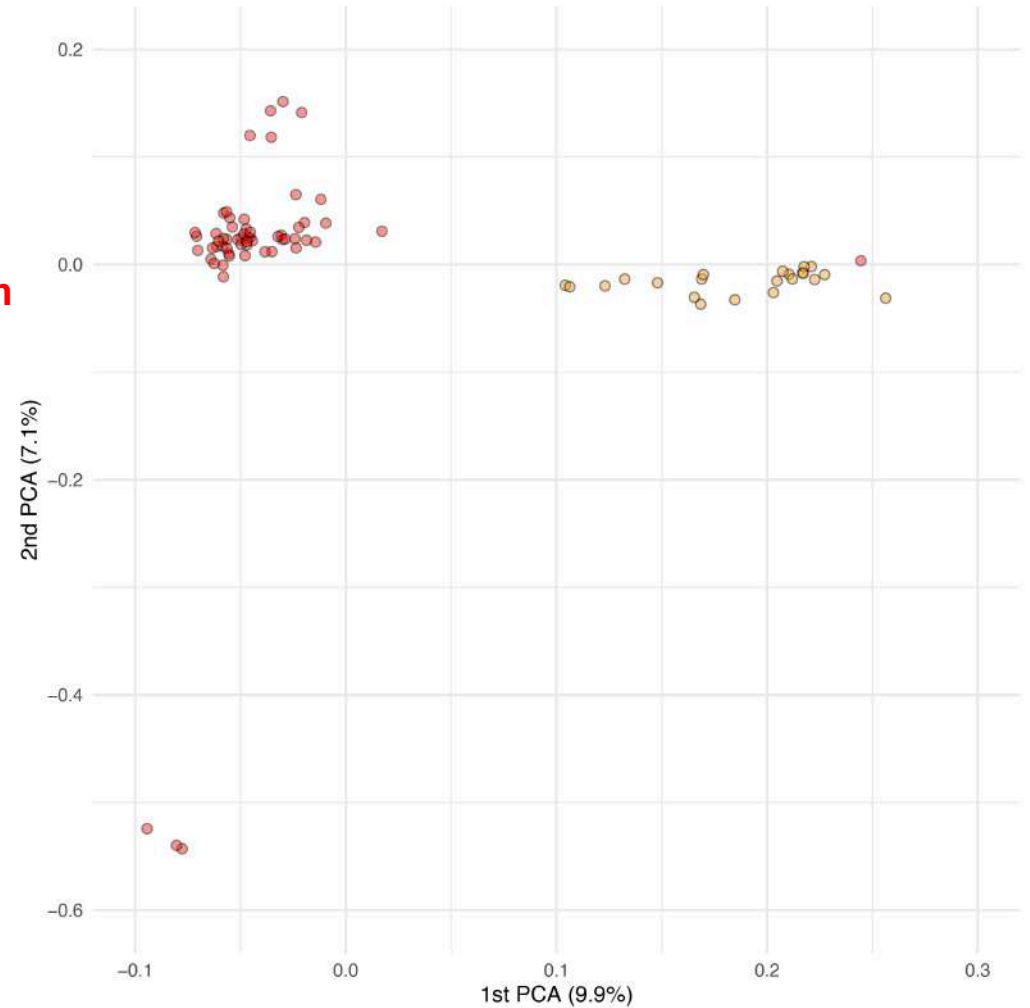
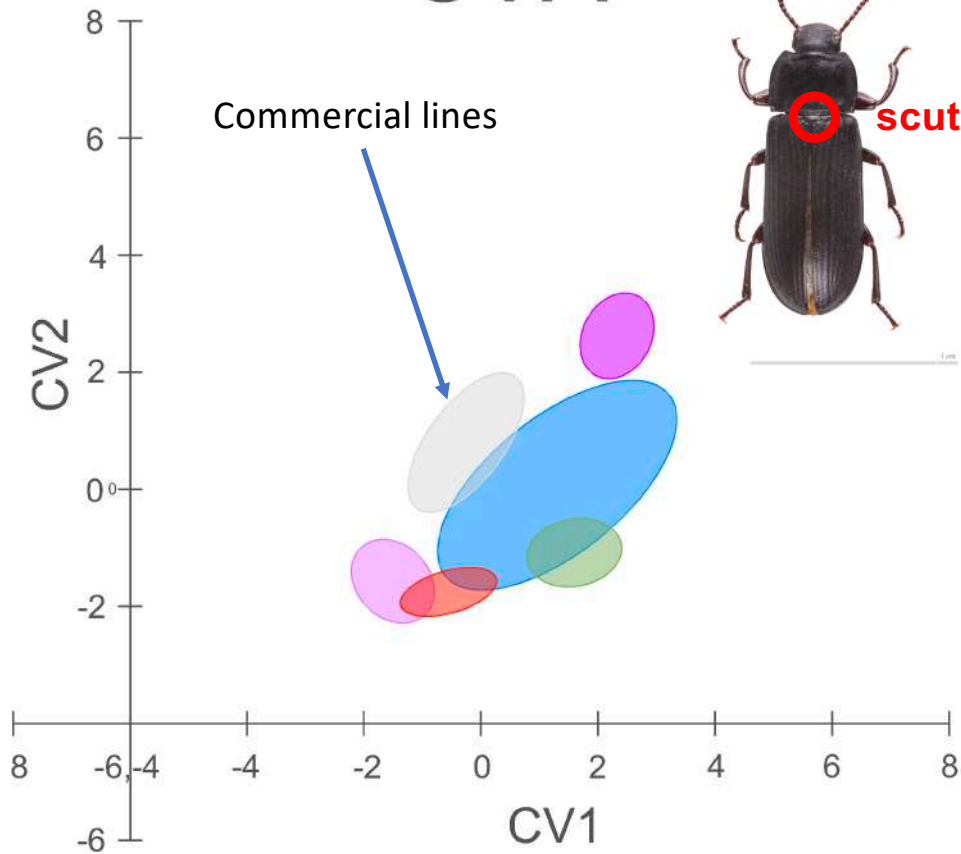
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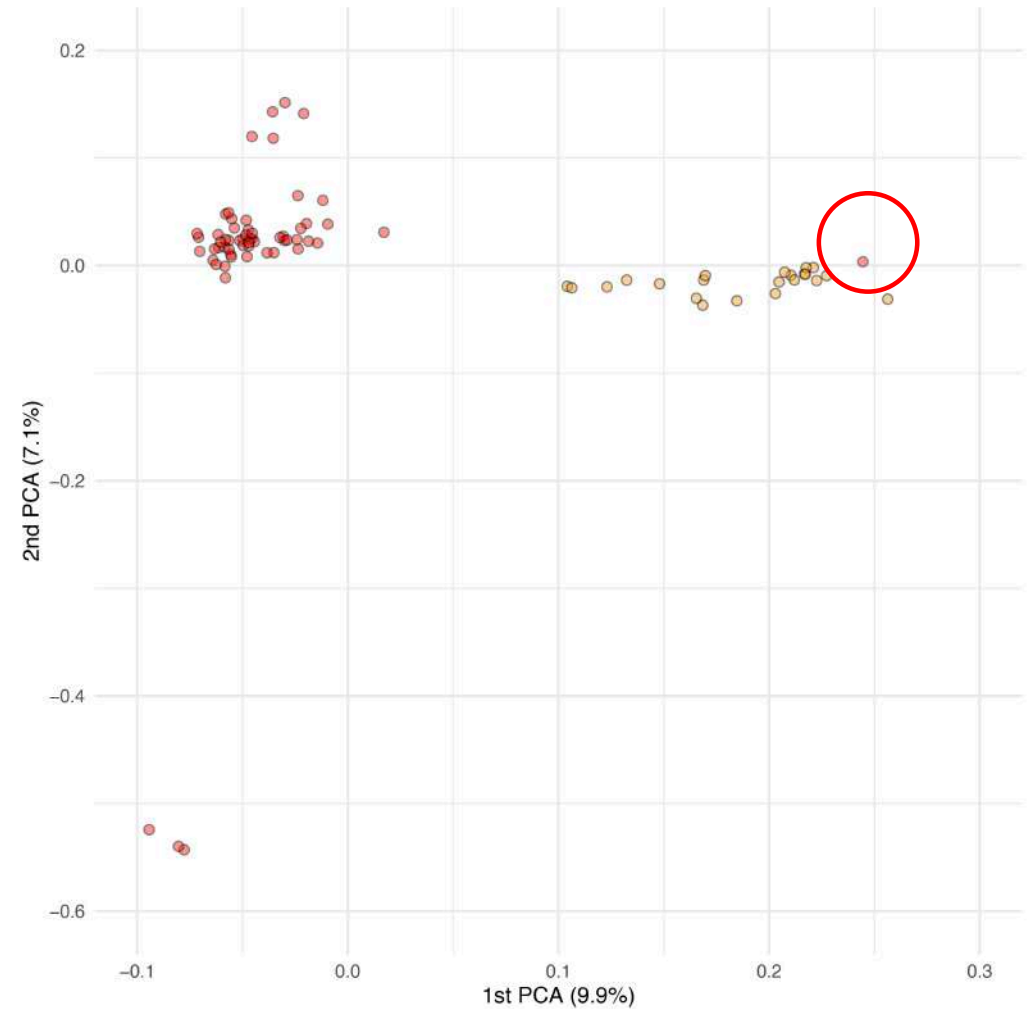
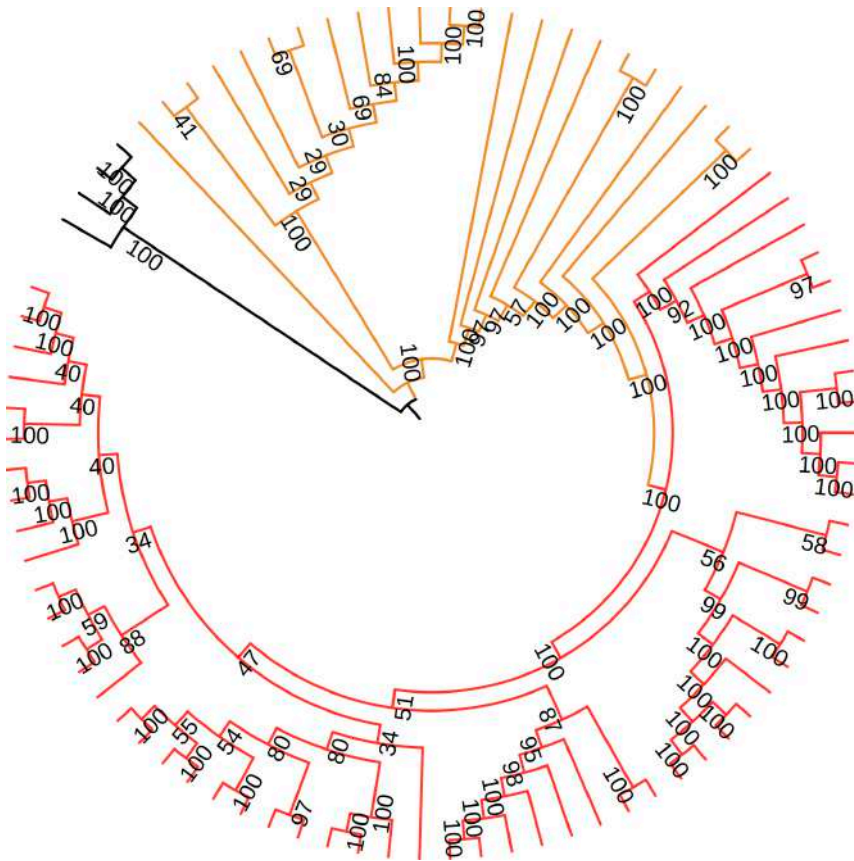


Modern & ancient population diversity

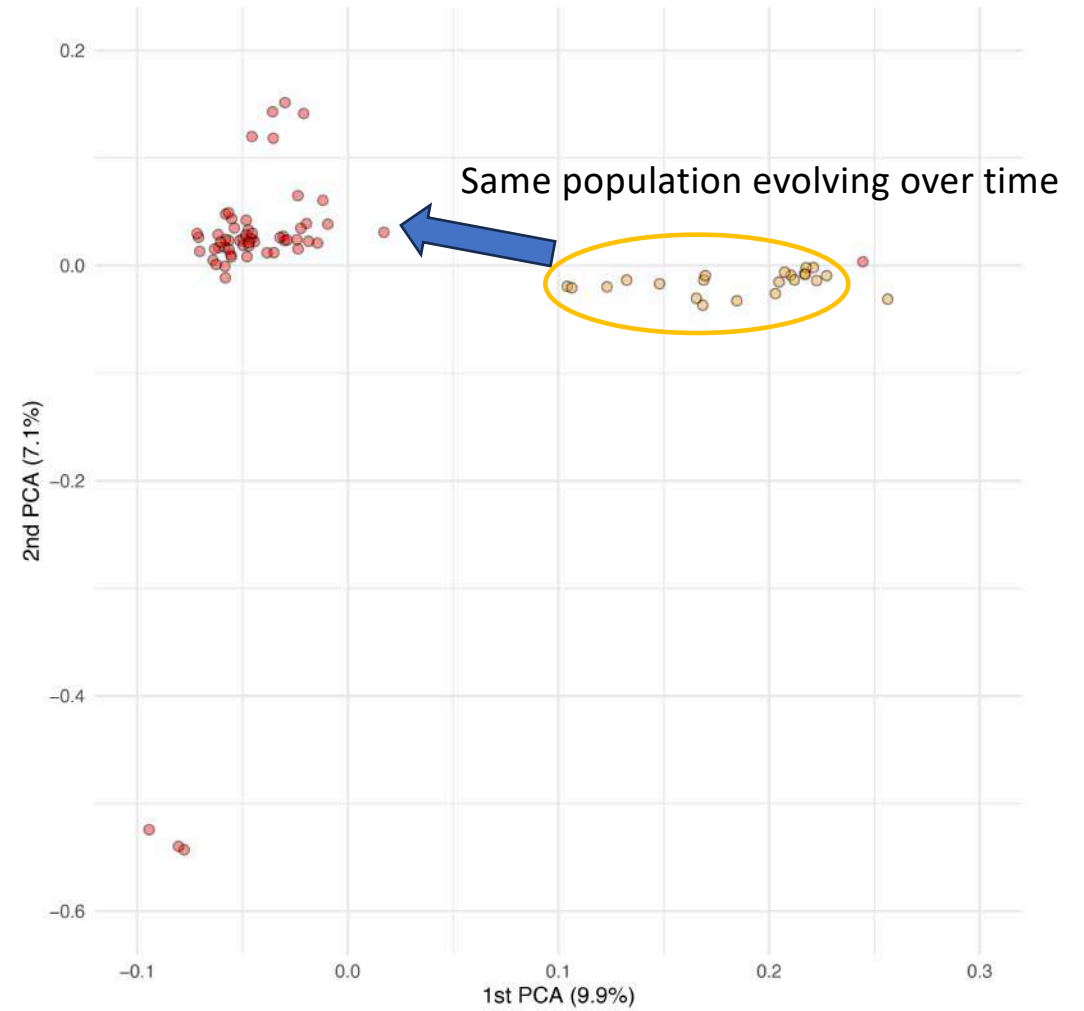
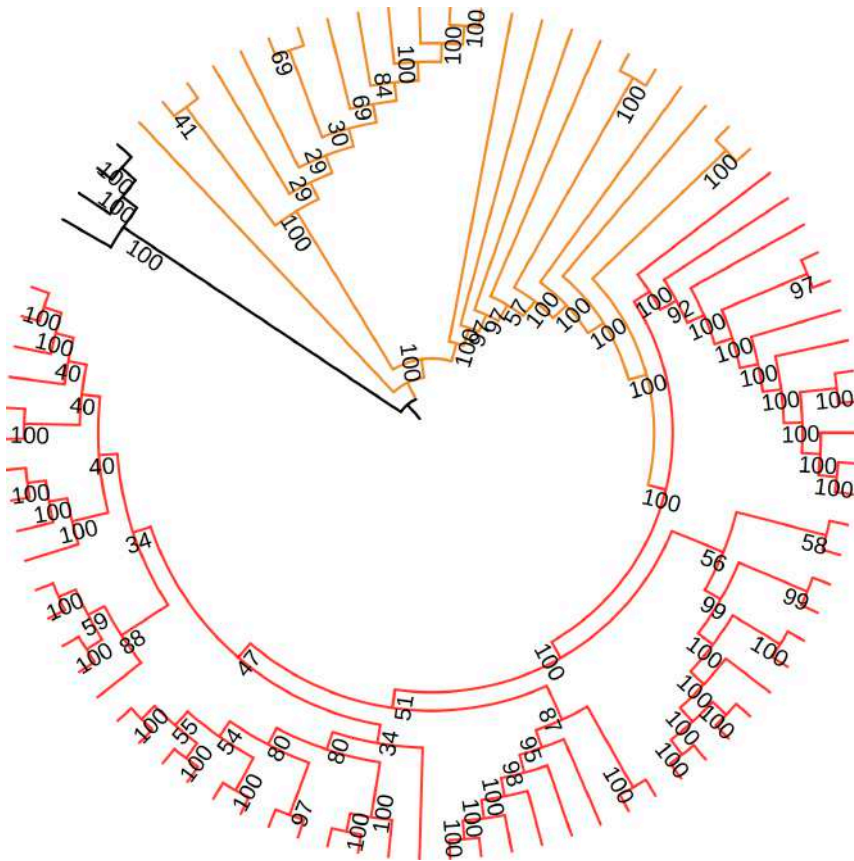
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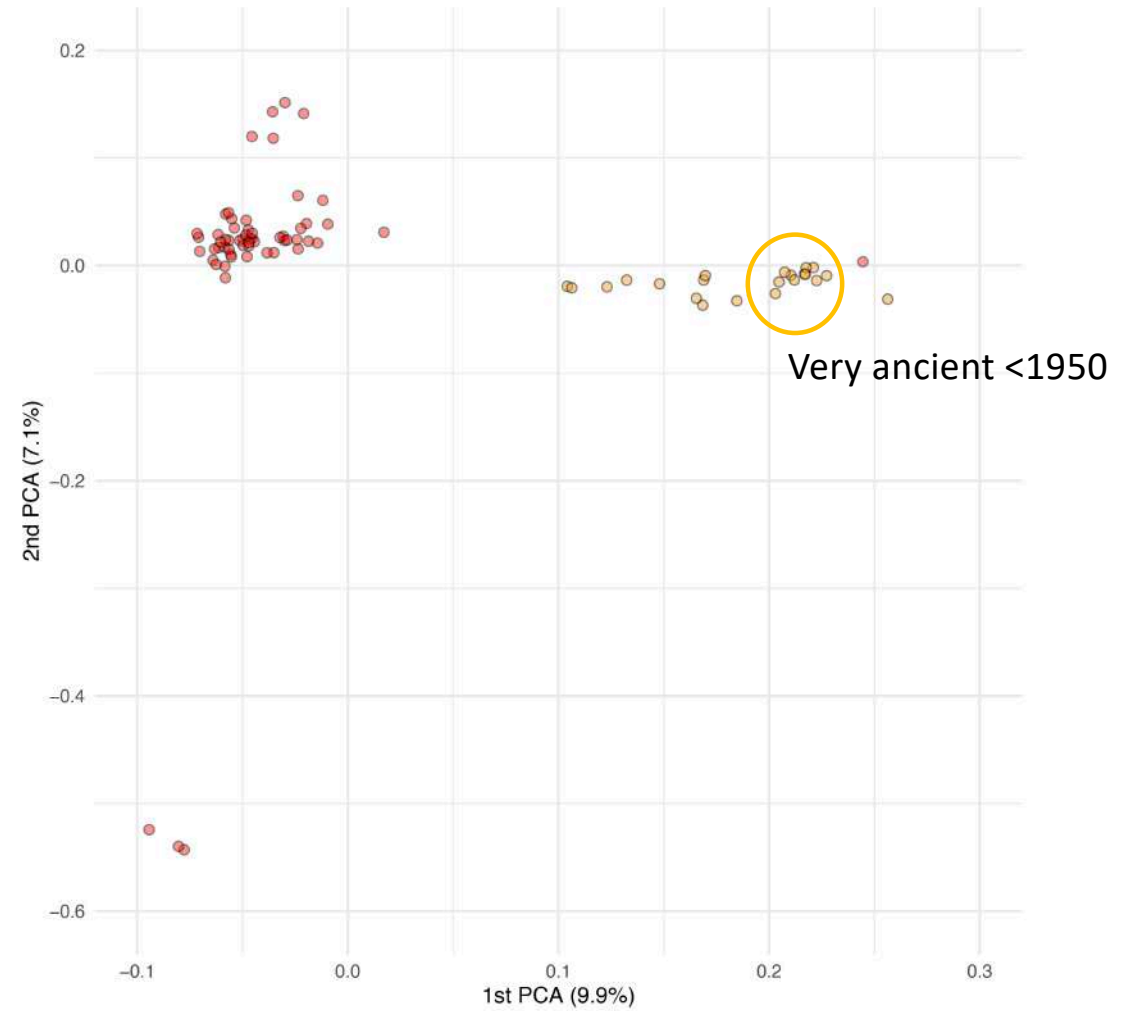
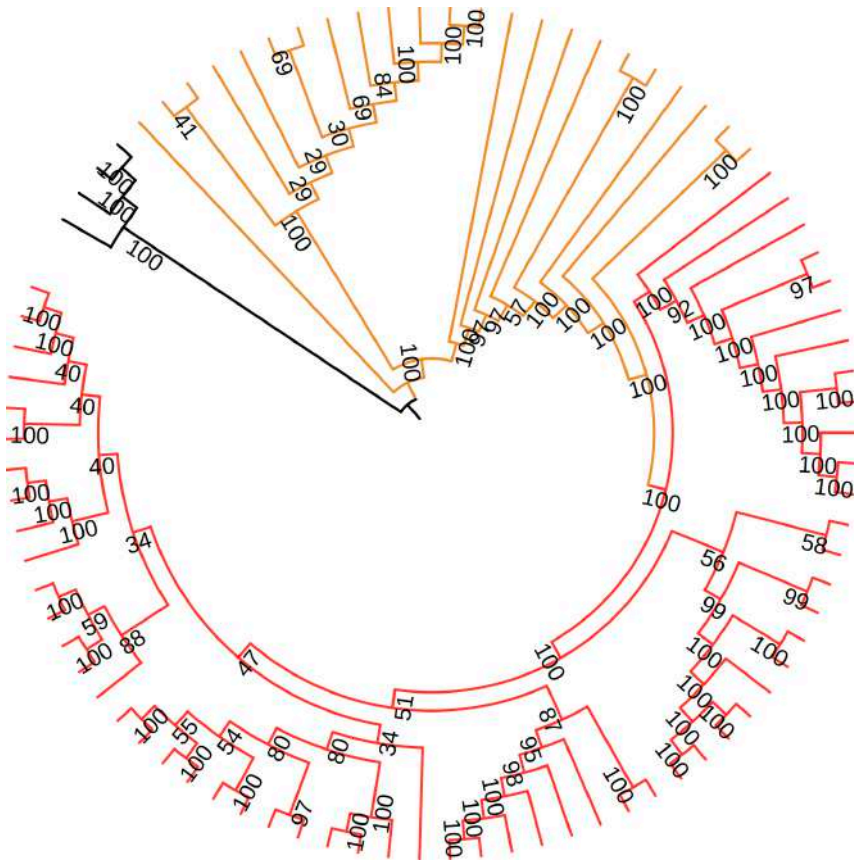
Modern & ancient population diversity



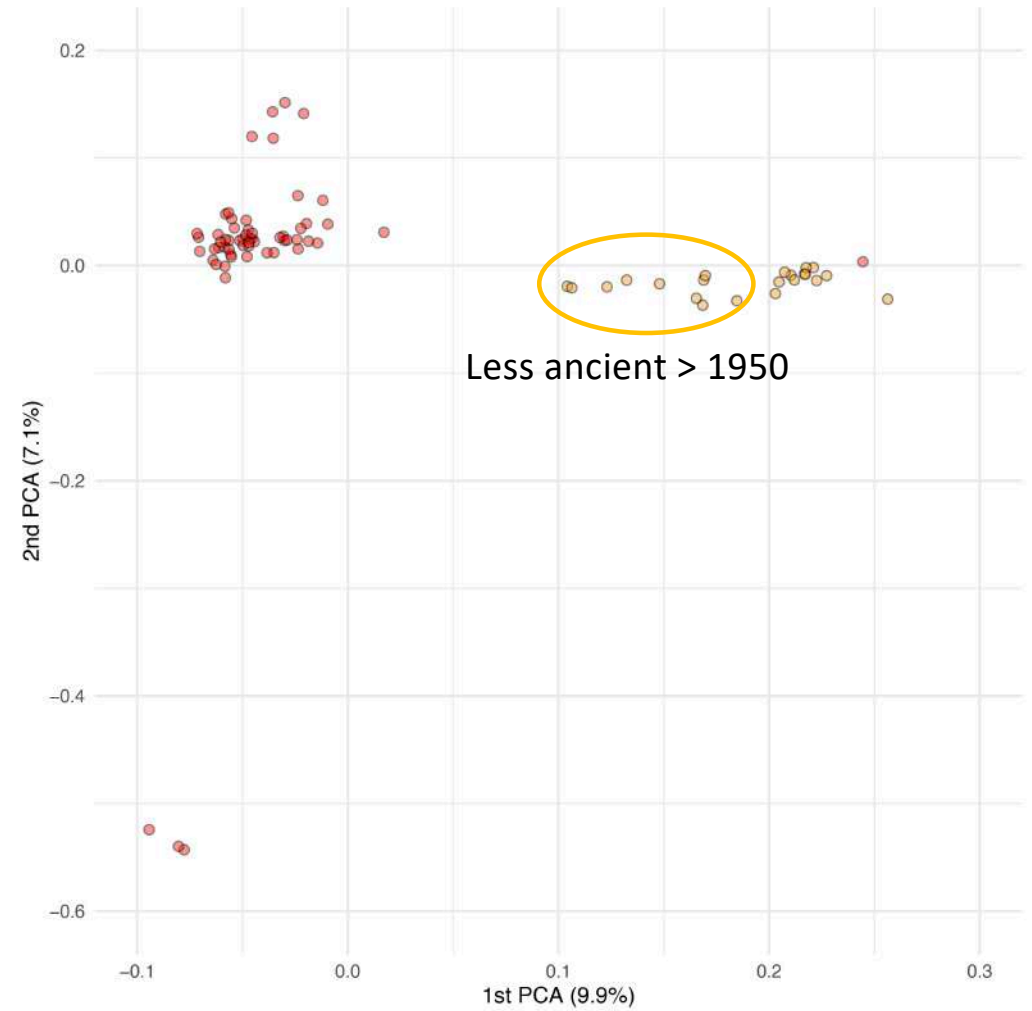
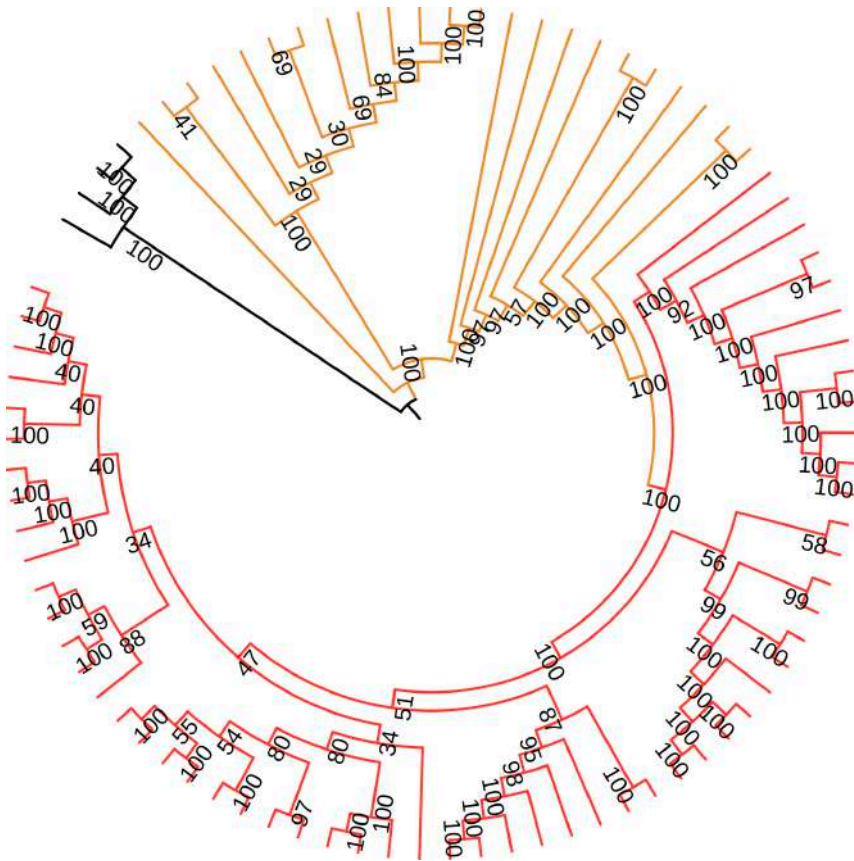
Edible insect domestication



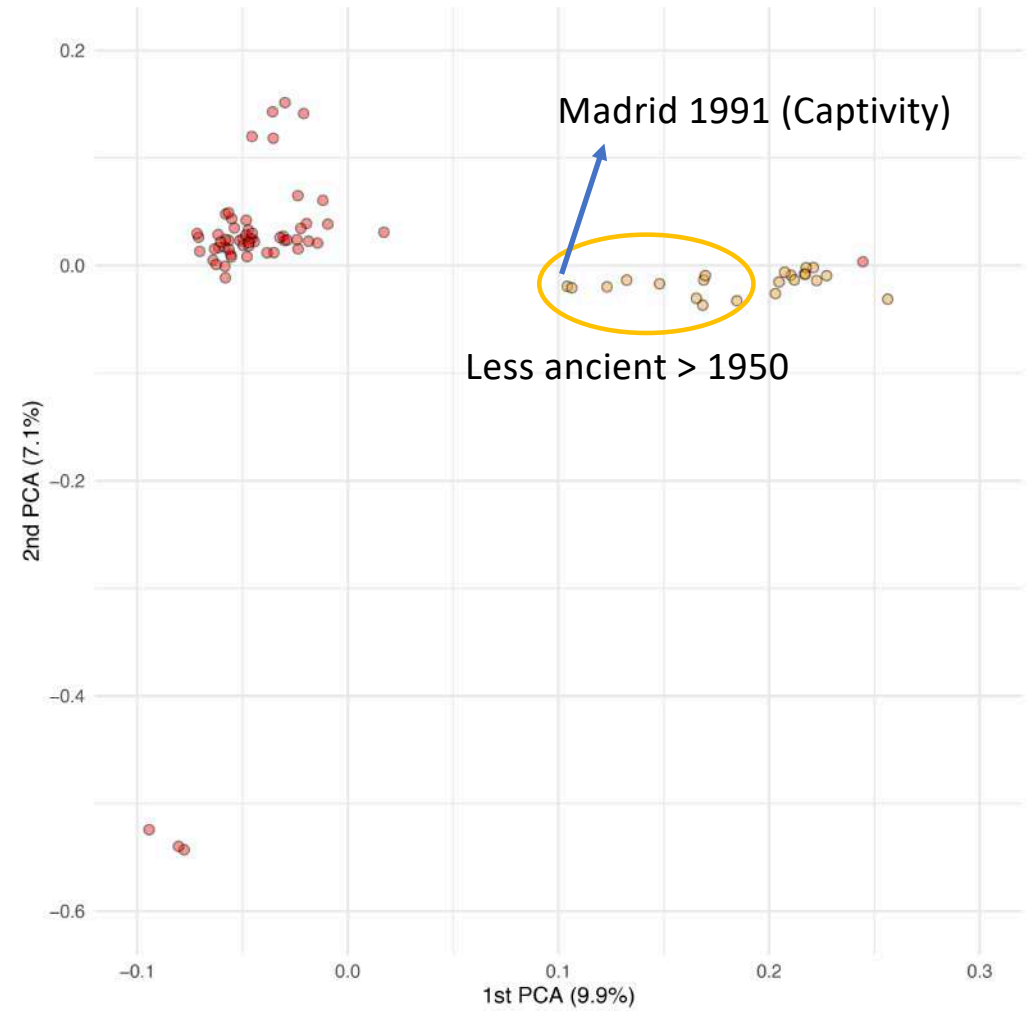
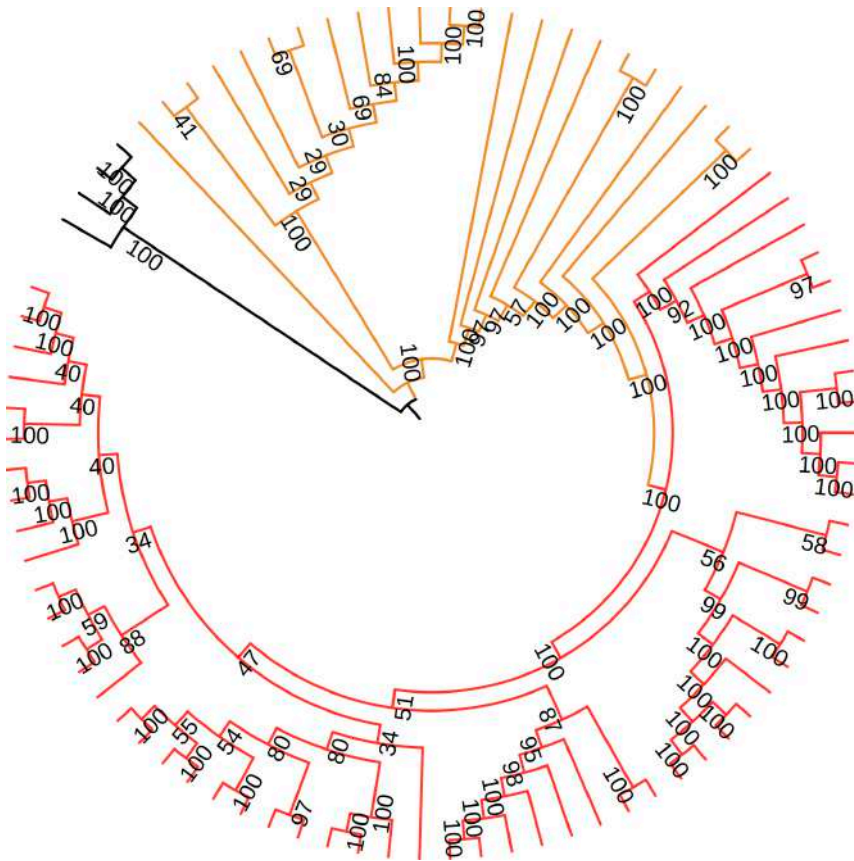
Ancient diversity



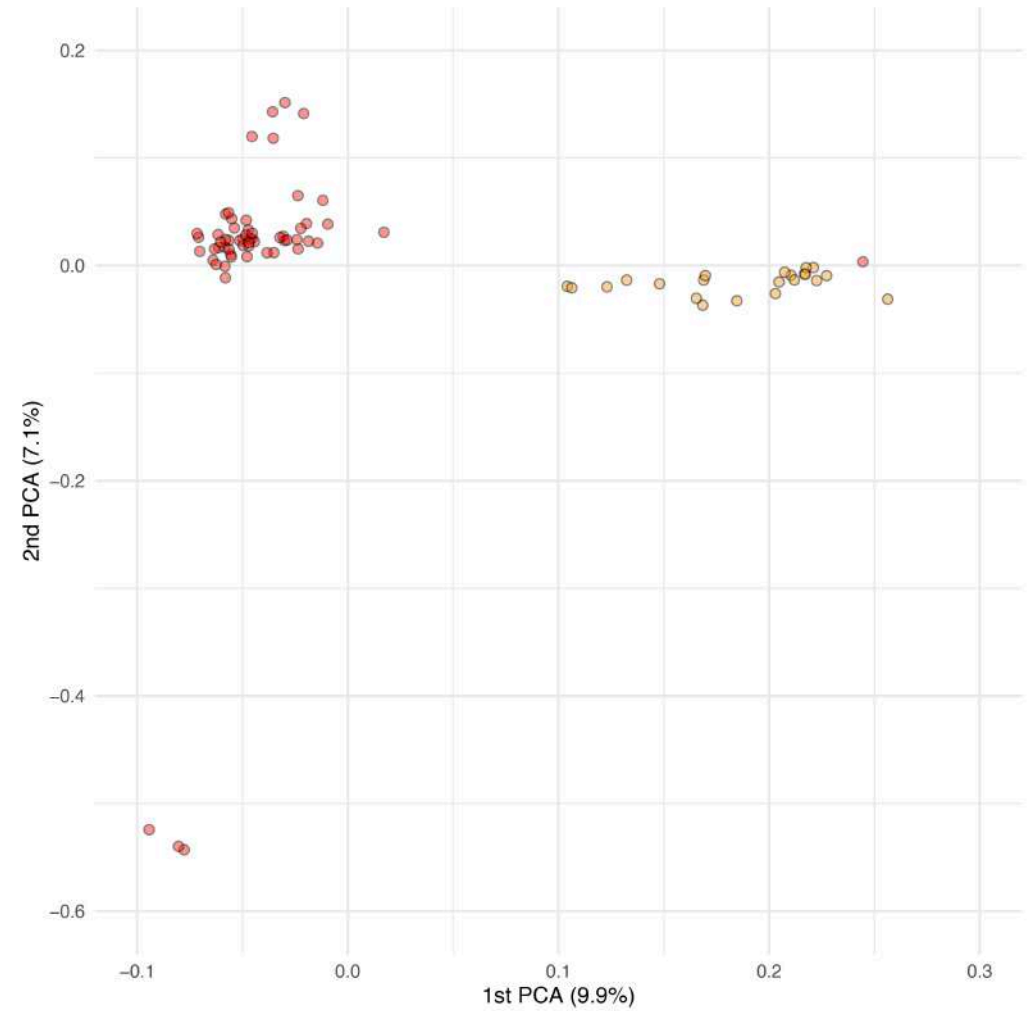
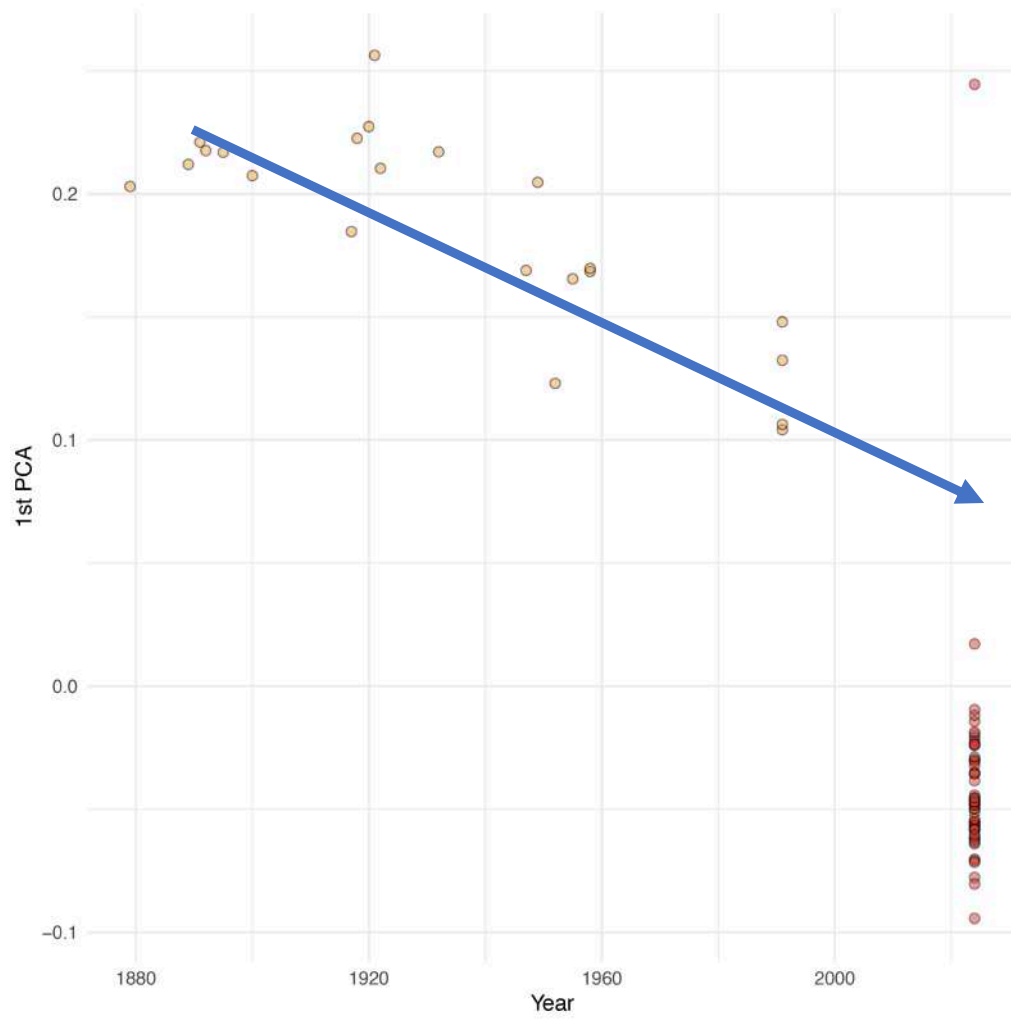
Ancient diversity



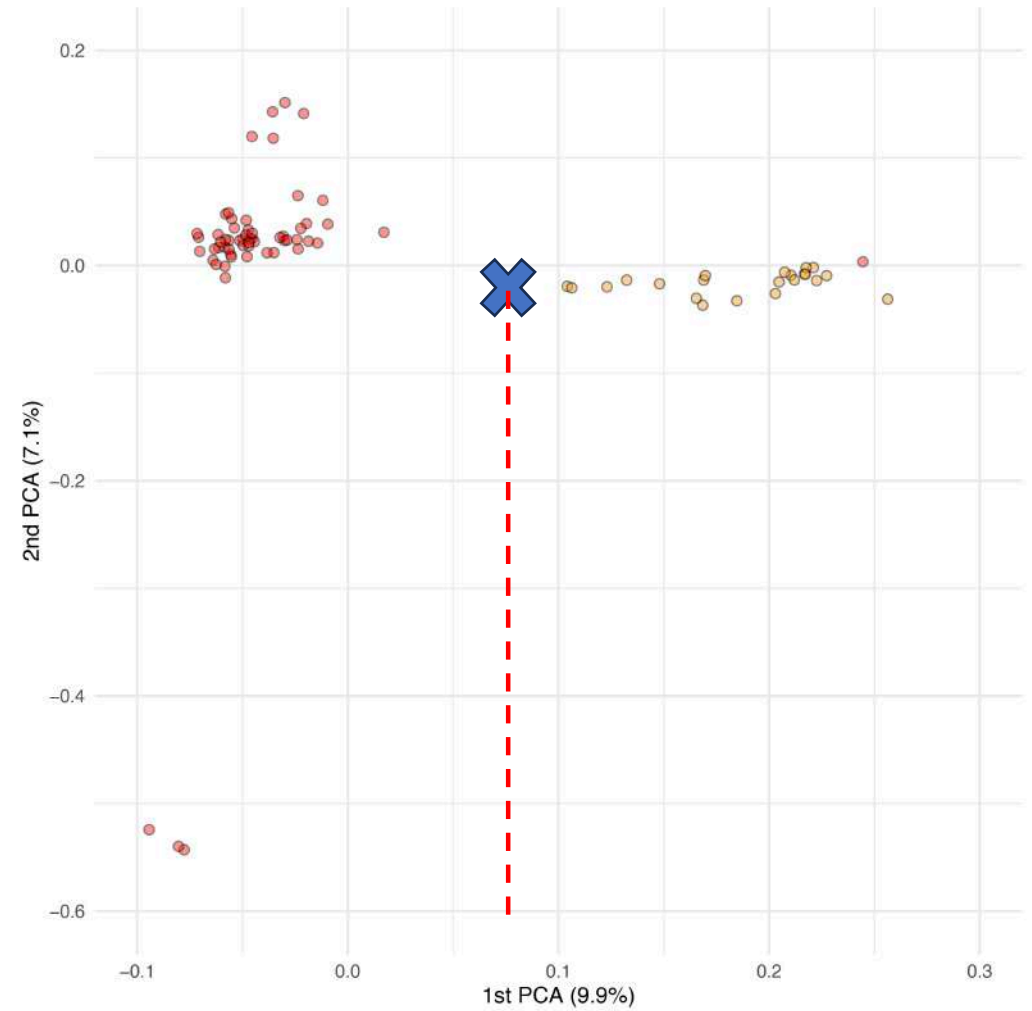
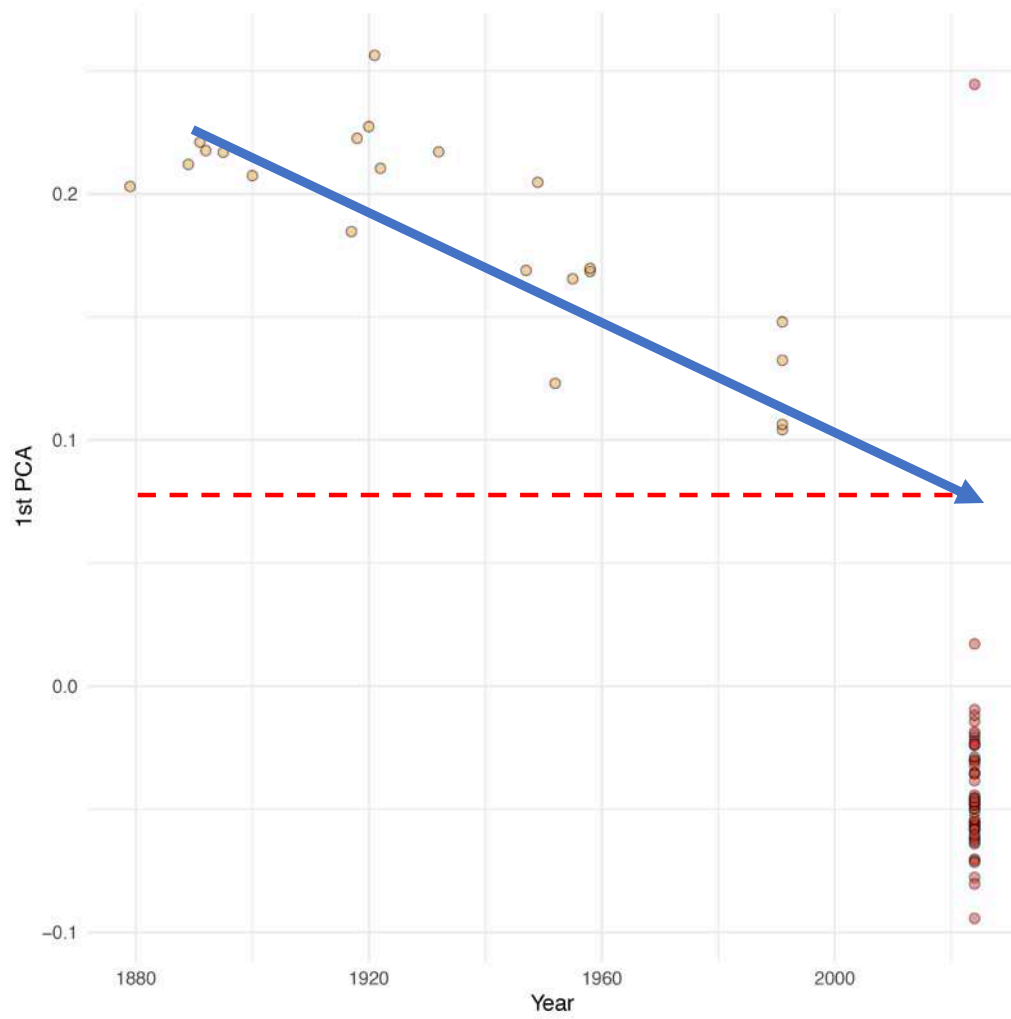
Ancient diversity



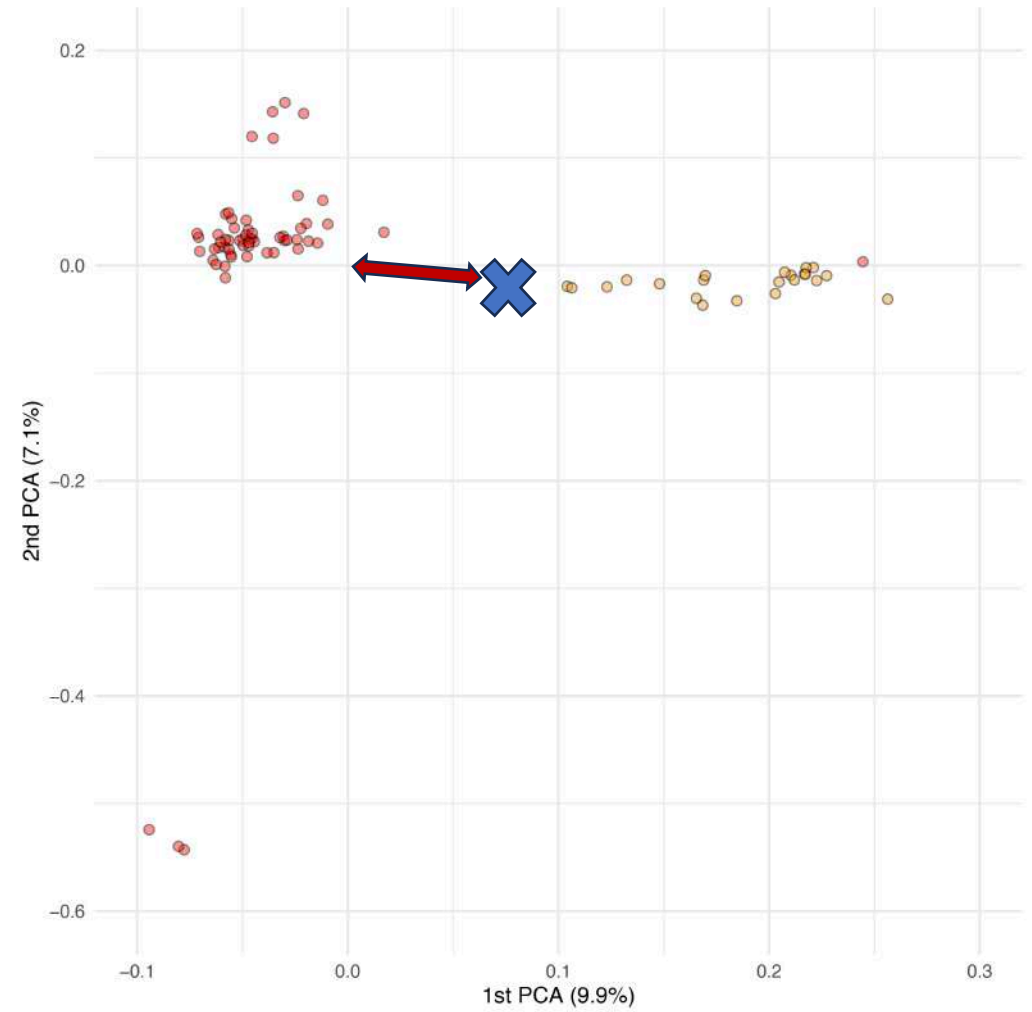
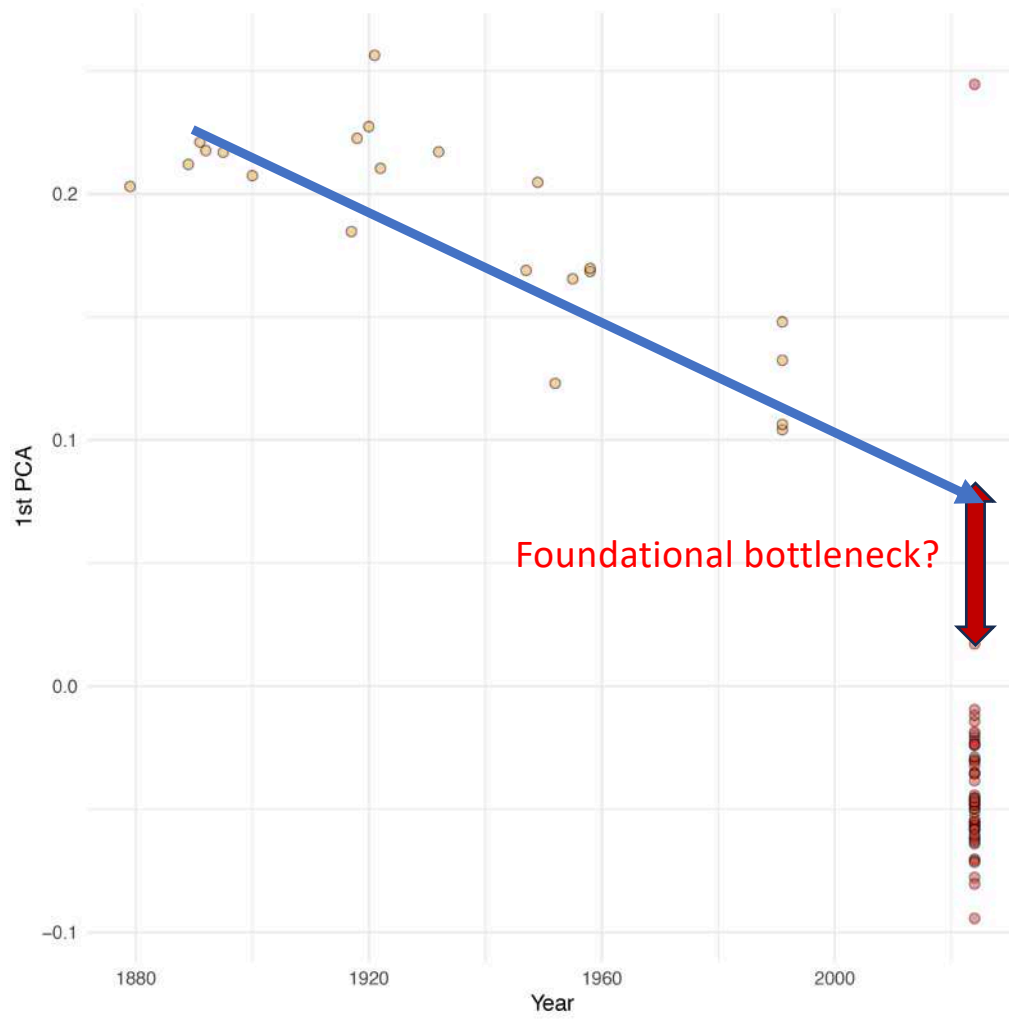
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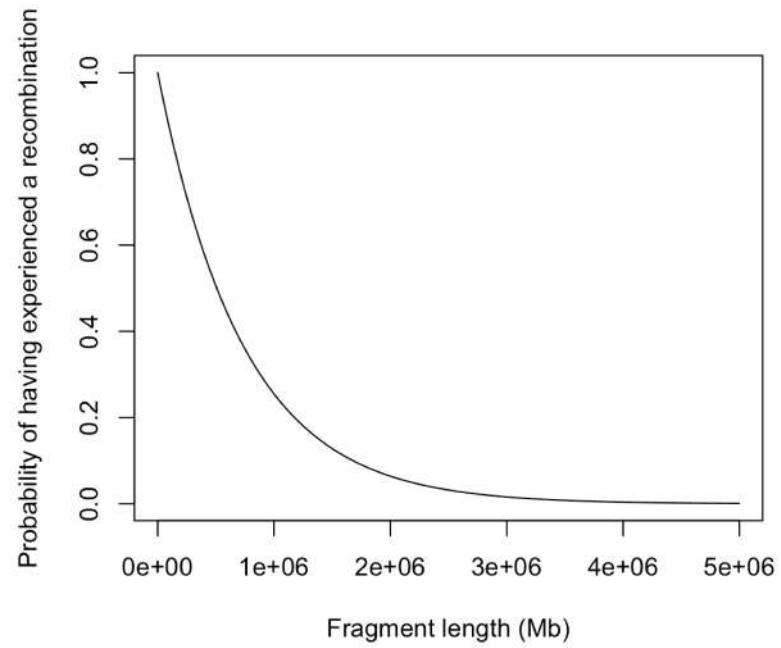
Ancient diversity



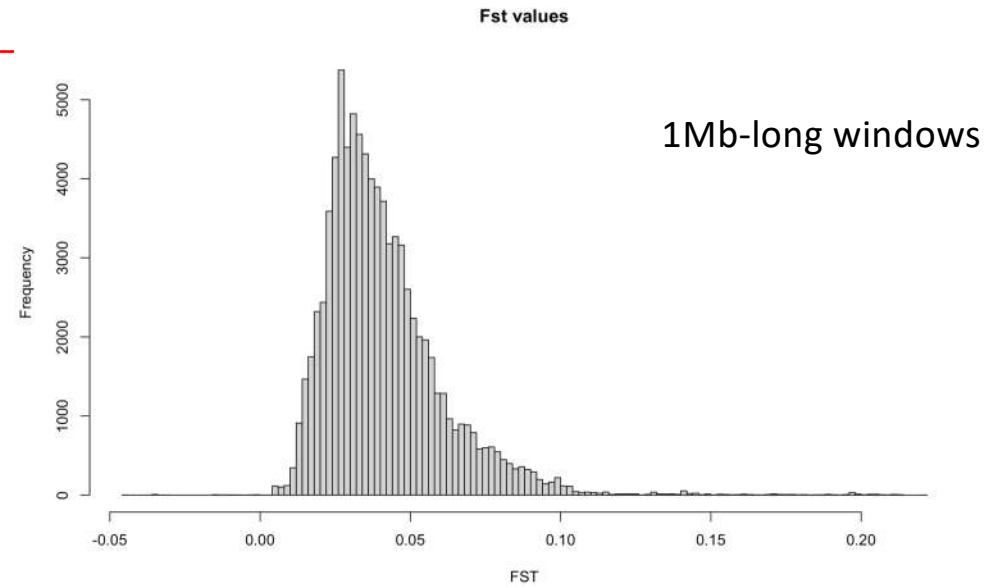
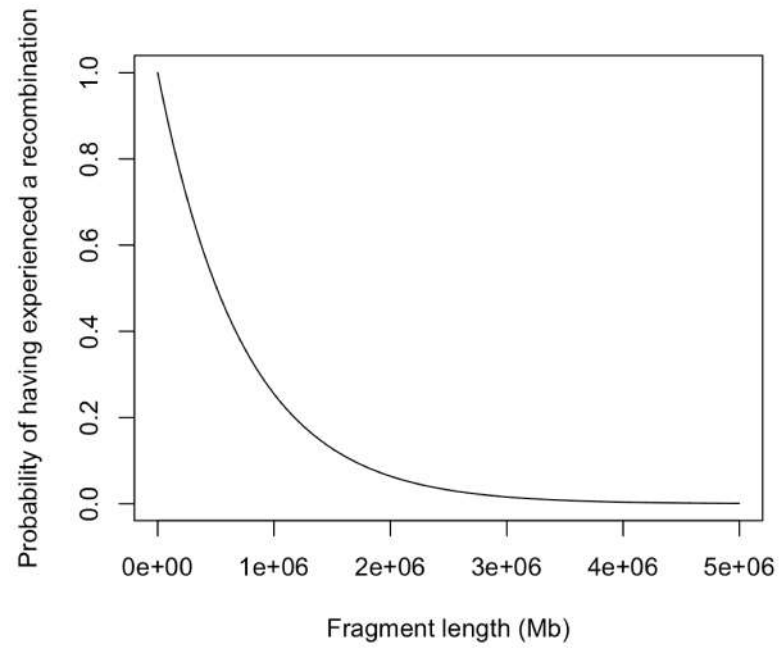
Ancient diversity



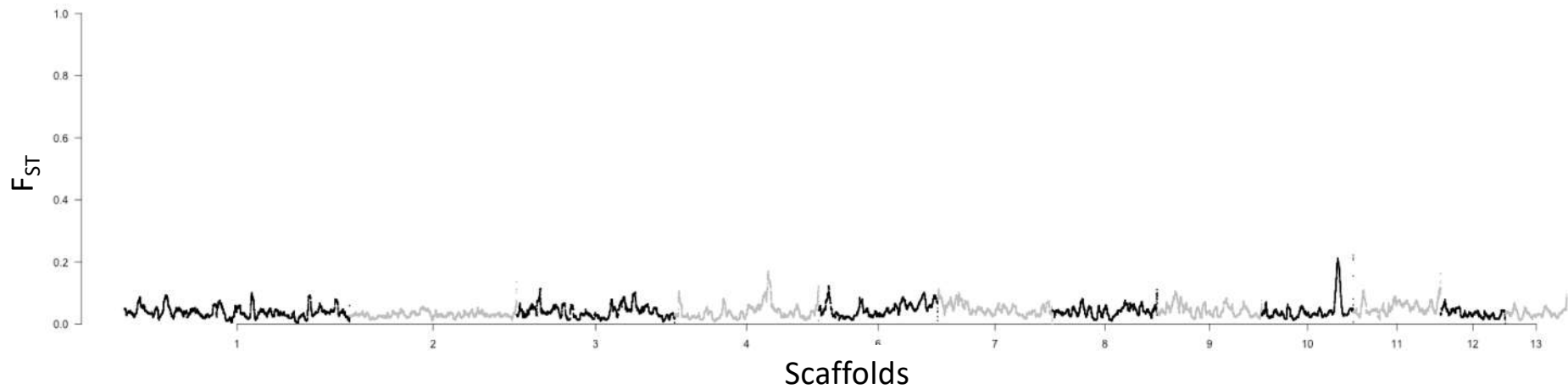
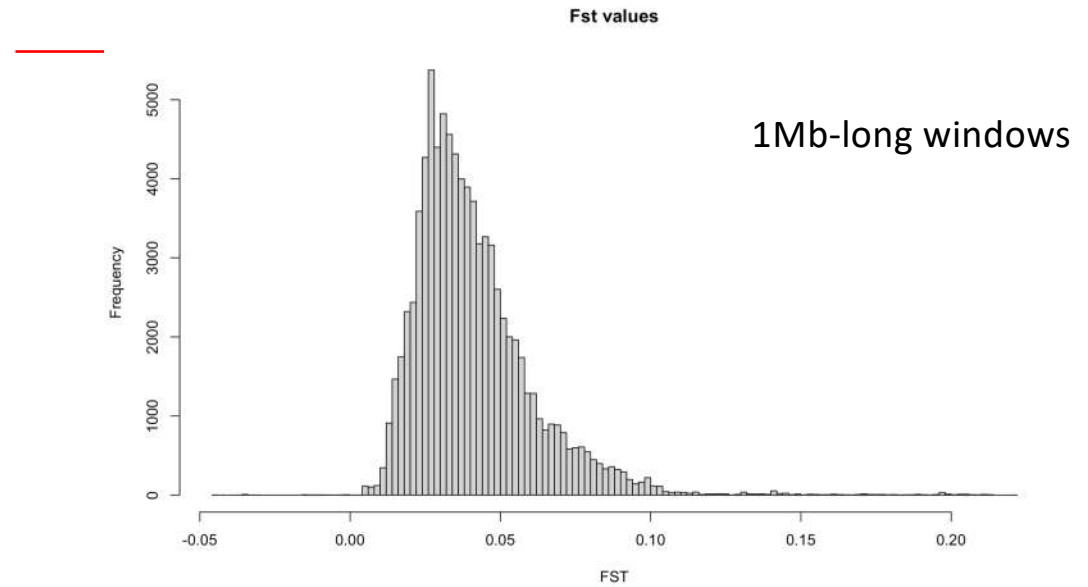
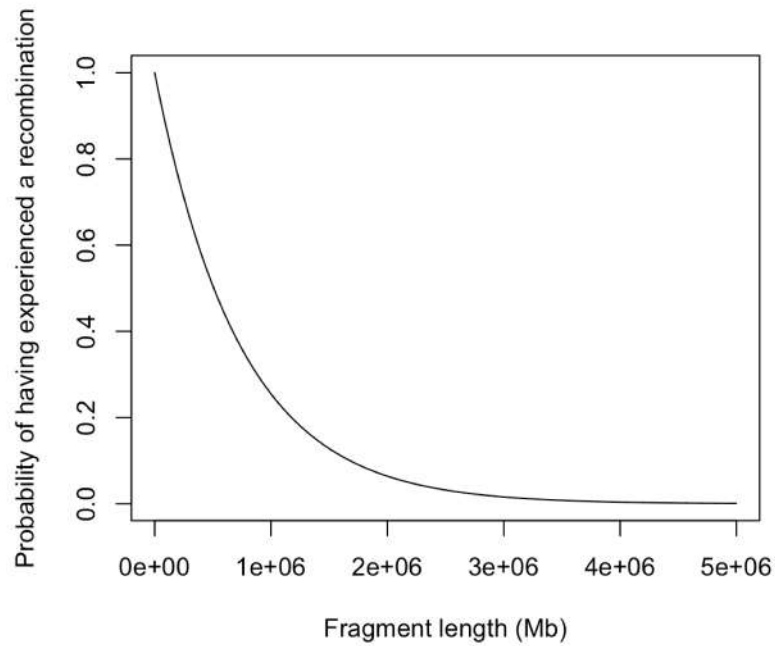
Genetic differentiation



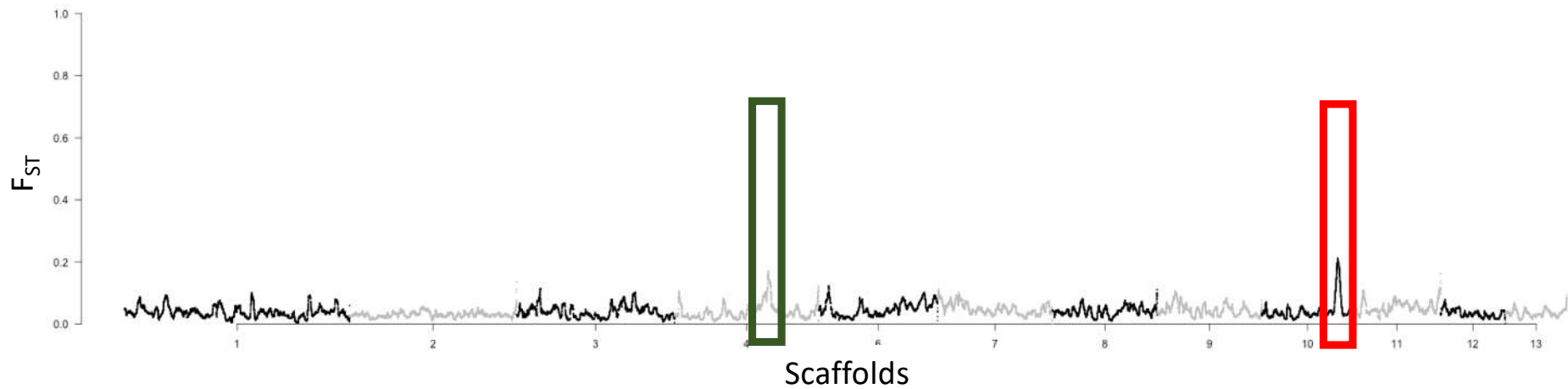
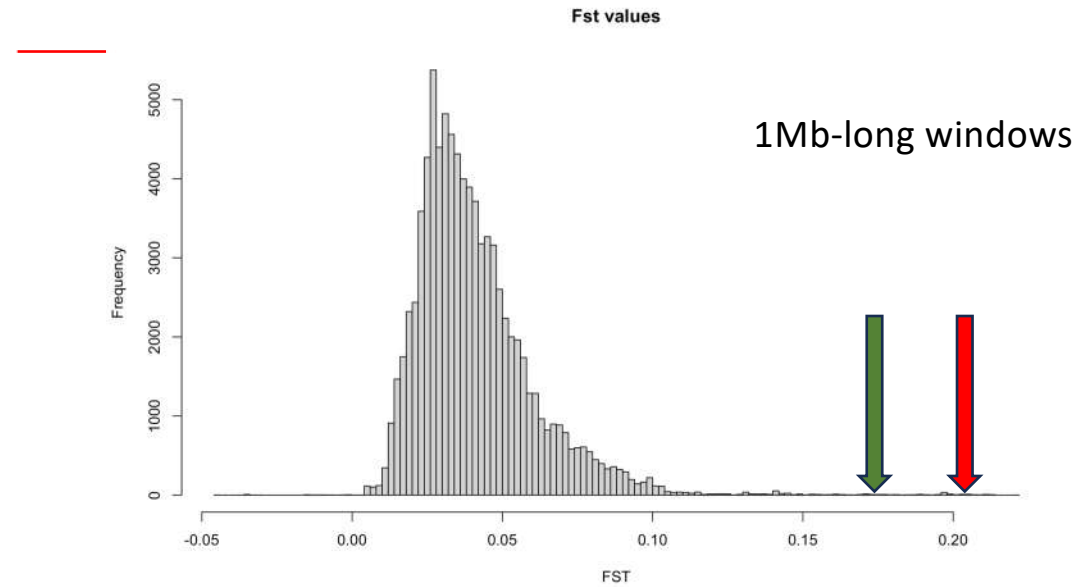
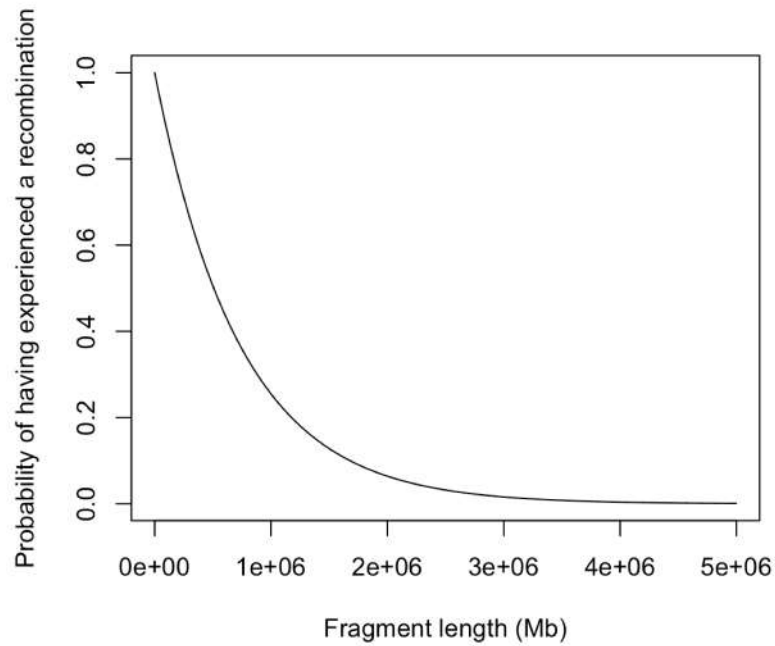
Genetic differentiation



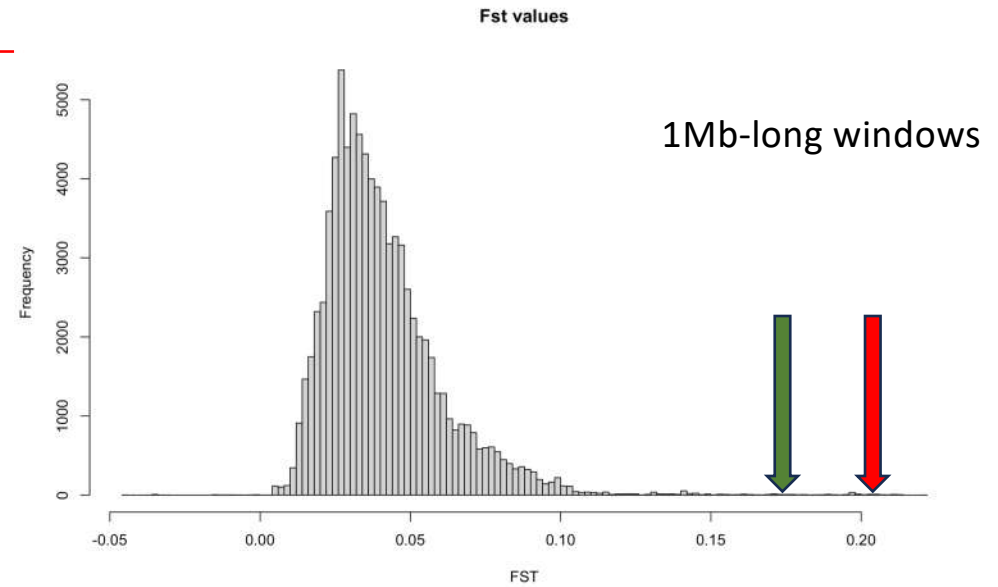
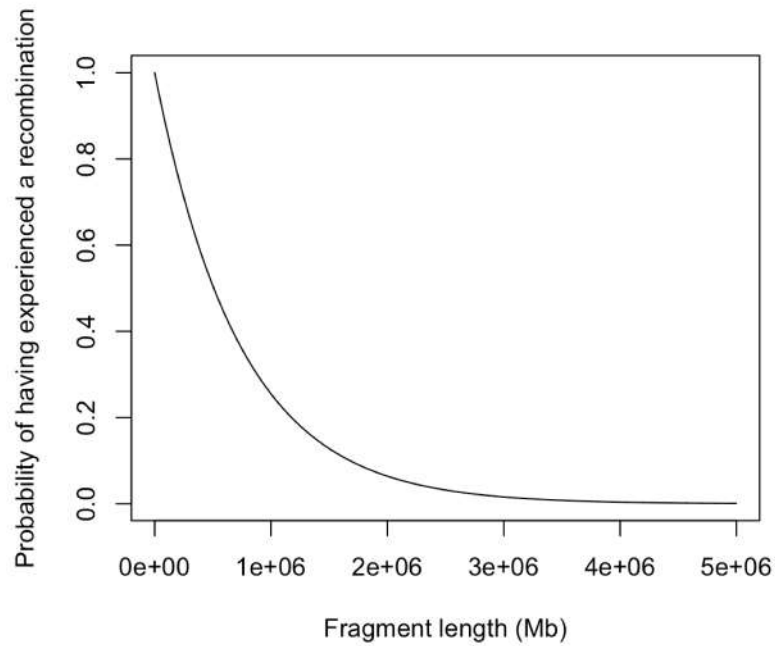
Genetic differentiation



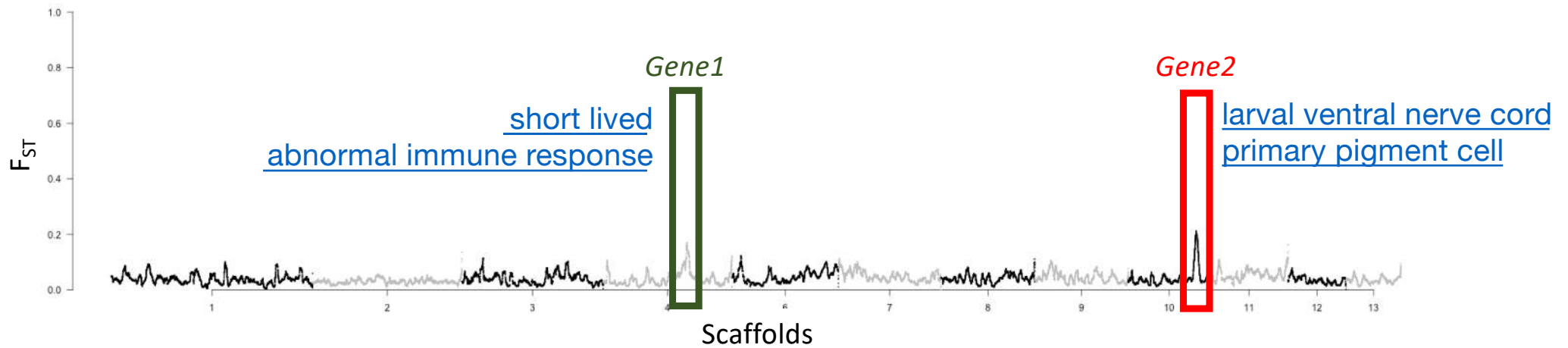
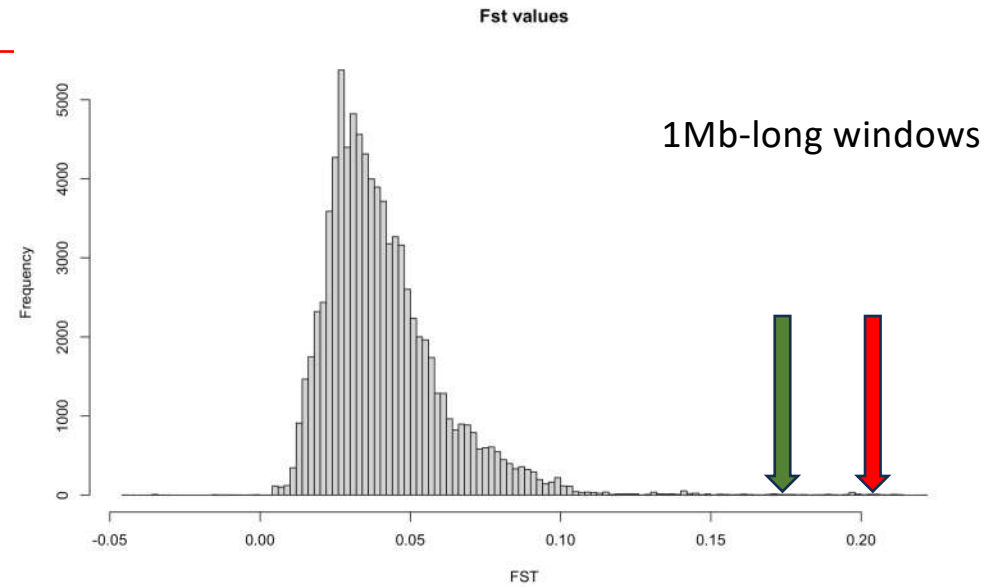
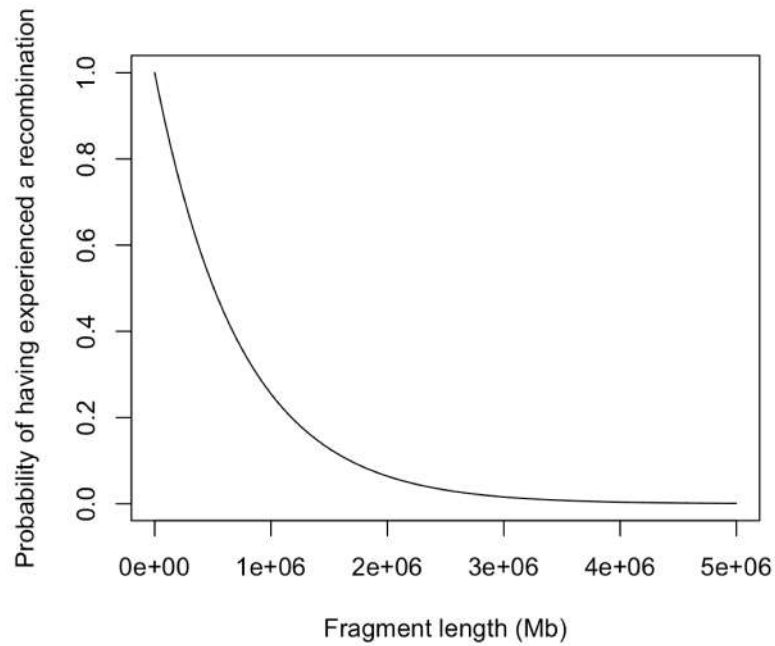
Genetic differentiation



Genetic differentiation



Genetic differentiation



THANKS!
(especially to our collaborators)

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<https://www.ibe.upf-csic.es/ancient-population-genomics>



*"Genomic changes underlying domestication: novel hypotheses based on edible insects mass-reared within the EU" (**DOMEUINSTITUTE**; PID2022-142607NA-I00) funded by MCIN/ AEI/10.13039/501100011033/*