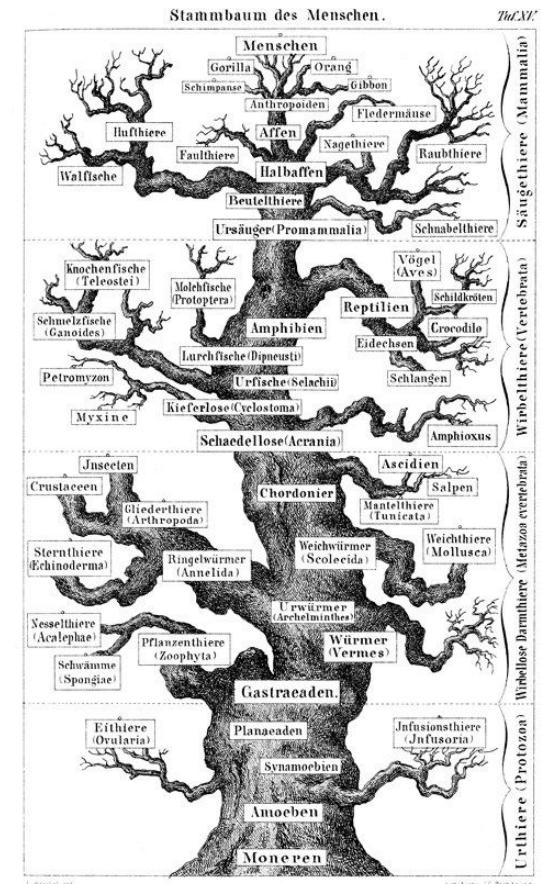
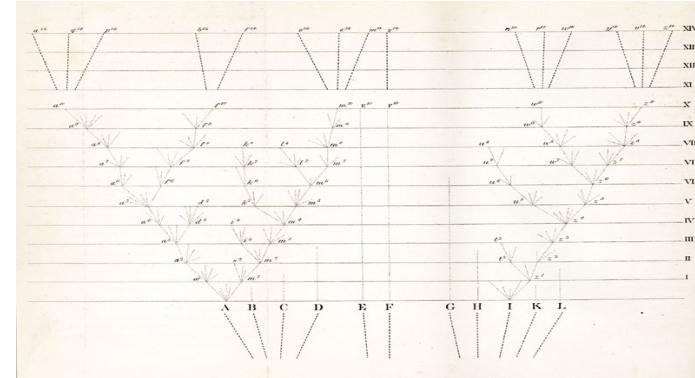
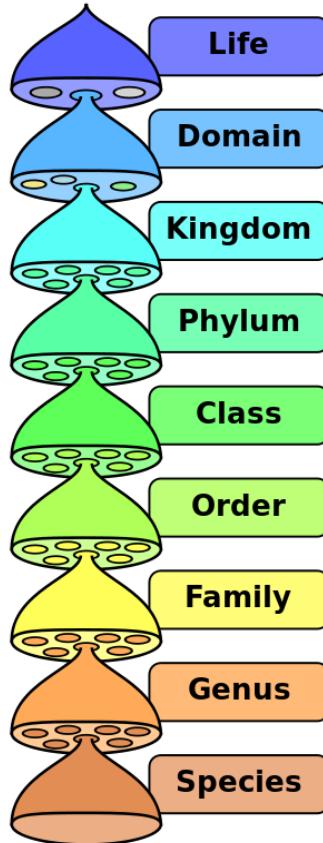


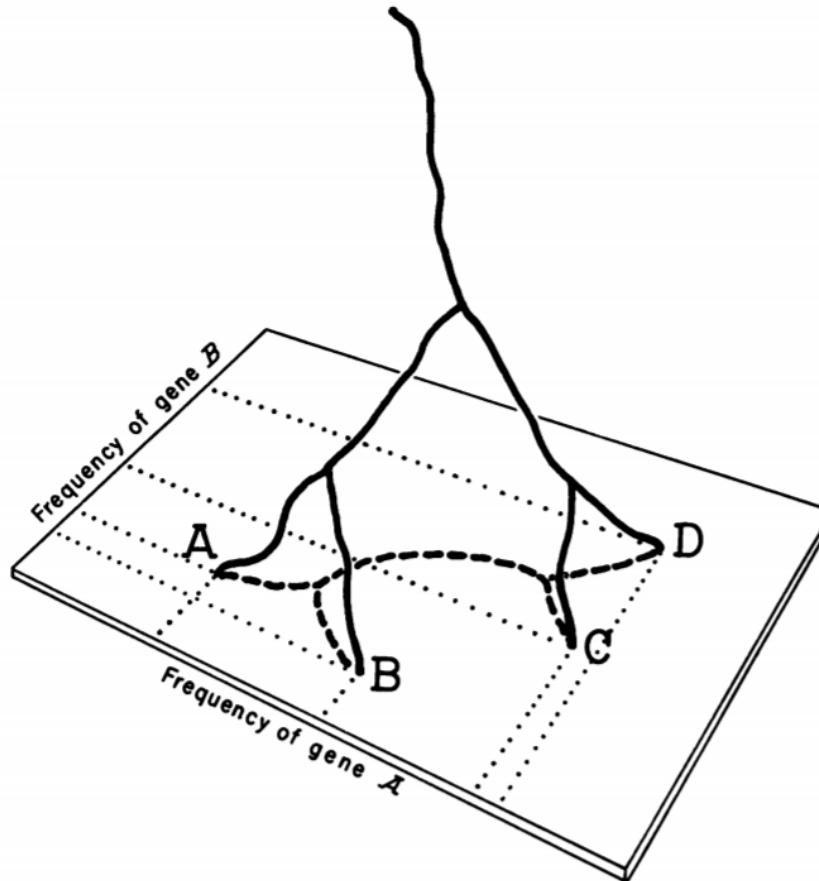
# Trees, Admixture graphs and population structure

# Using trees to describe (human) population structure

# Trees are foundational to Systematics and Evolution

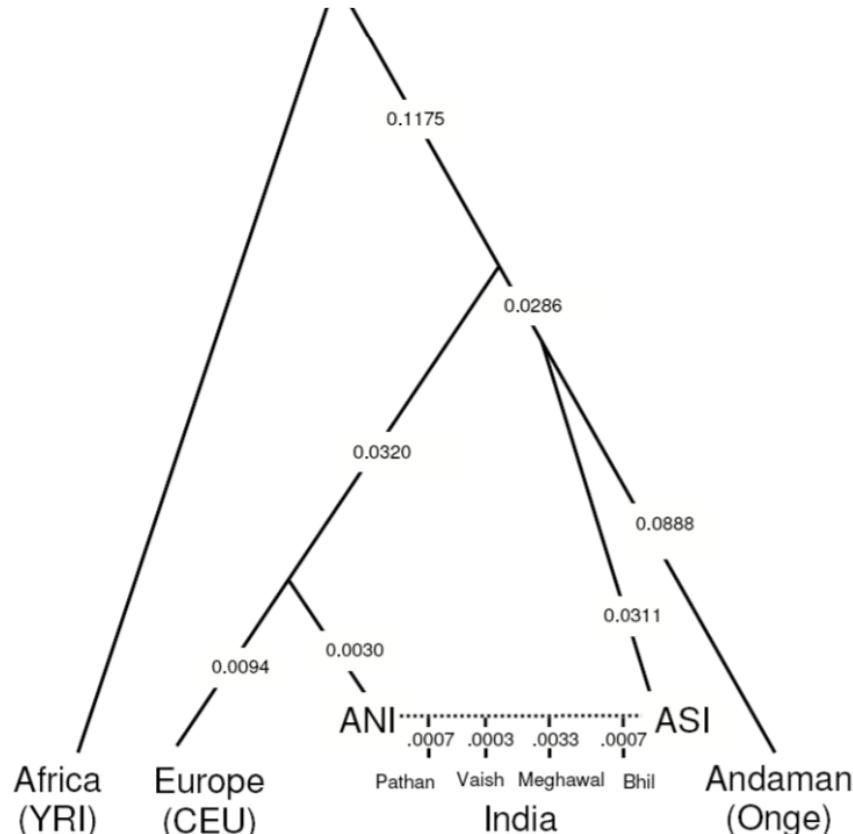


# Where do trees come from?



Cavalli-Sforza & Edwards, 1967

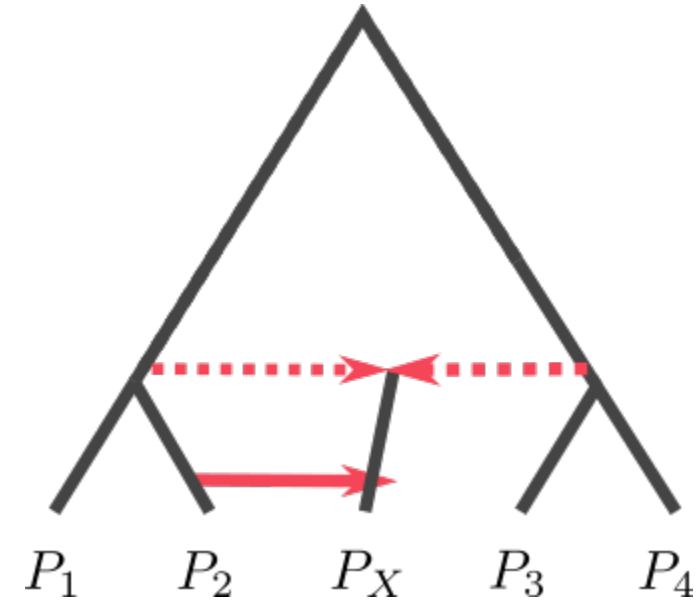
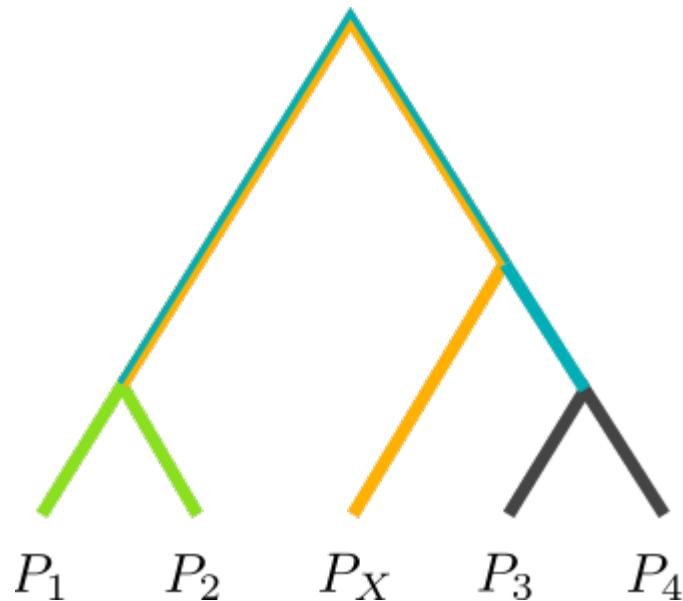
# But when does this model break?



**Figure 4.**

A model relating the history of Indian and non-Indian groups. Modeling the Pathan, Vaish,

# Trees and Admixture Graphs



# Estimating Admixture Graphs

Admixtools / treemix



## Admixture graphs

Robert Maier

OPEN  ACCESS Freely available online

 PLOS GENETICS

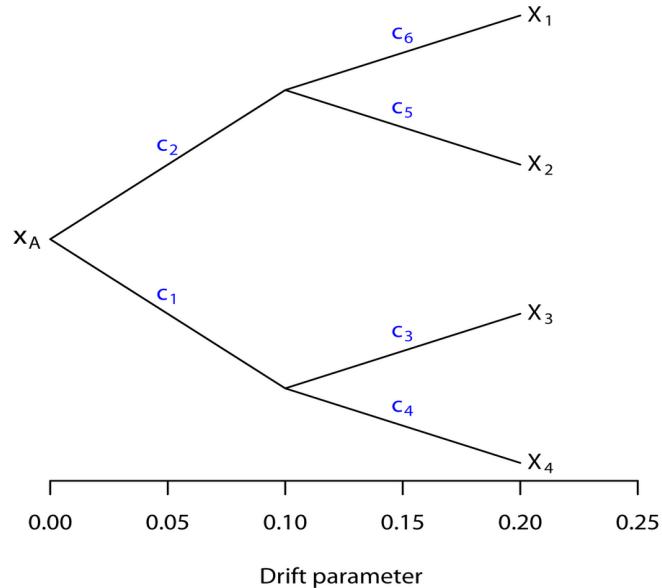
## Inference of Population Splits and Mixtures from Genome-Wide Allele Frequency Data

Joseph K. Pickrell<sup>1,\*</sup>, Jonathan K. Pritchard<sup>1,2,\*</sup>

# Inference of Population Splits and Mixtures from Genome-Wide Allele Frequency Data

Joseph K. Pickrell<sup>1,\*</sup>, Jonathan K. Pritchard<sup>1,2\*</sup>

A. Example tree

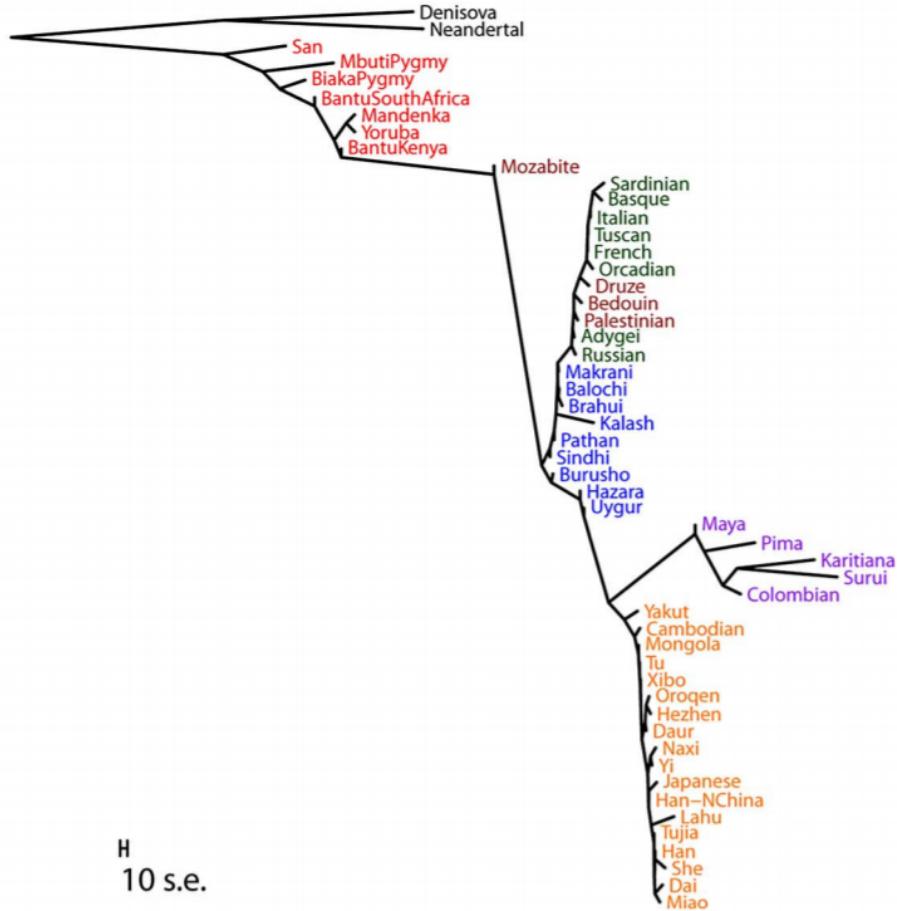


B. Covariance matrix for tree in A.

$x_1$	$c_2 + c_6$	$c_2$	0	0
$x_2$	$c_2$	$c_2 + c_5$	0	0
$x_3$	0	0	$c_1 + c_3$	$c_1$
$x_4$	0	0	$c_1$	$c_1 + c_4$
	$x_1$	$x_2$	$x_3$	$x_4$

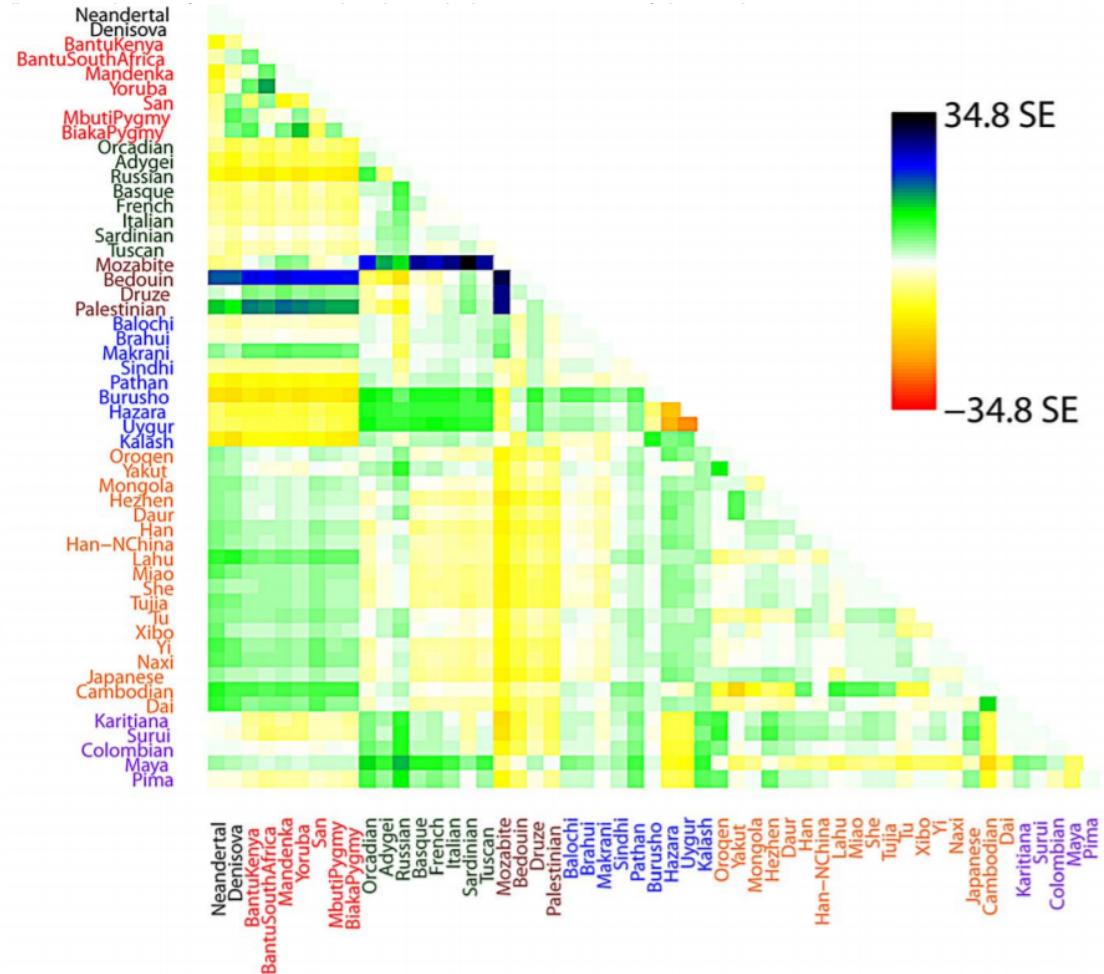
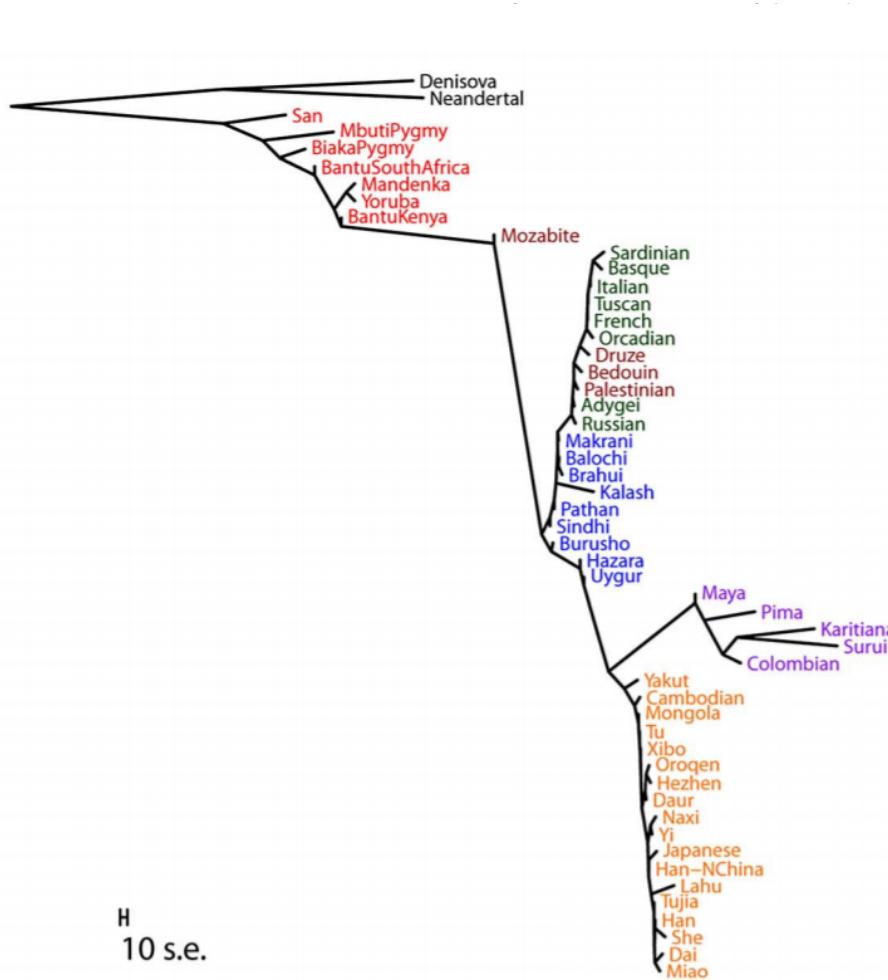
# Inference of Population Splits and Mixtures from Genome-Wide Allele Frequency Data

Joseph K. Pickrell<sup>1,\*</sup>, Jonathan K. Pritchard<sup>1,2,\*</sup>

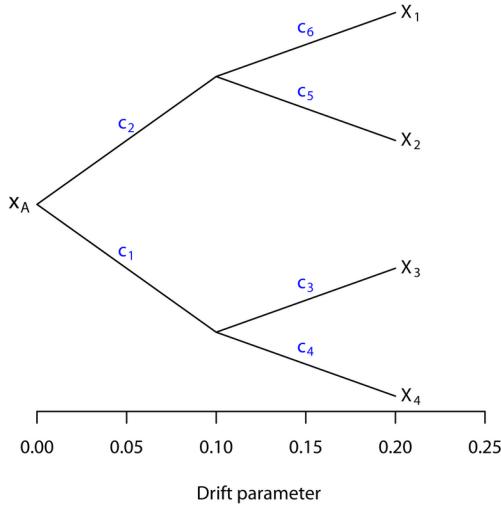


# Inference of Population Splits and Mixtures from Genome-Wide Allele Frequency Data

Joseph K. Pickrell<sup>1,\*</sup>, Jonathan K. Pritchard<sup>1,2,\*</sup>



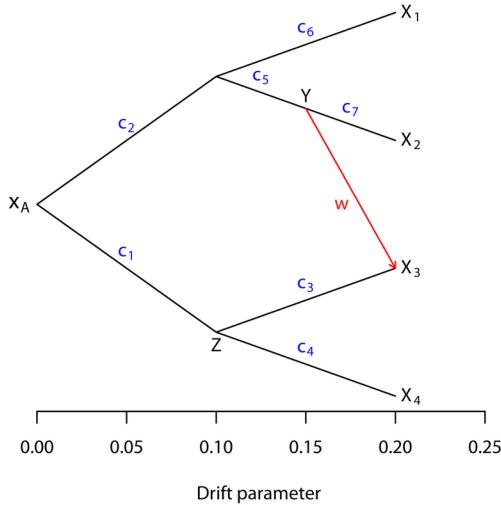
A. Example tree



B. Covariance matrix for tree in A.

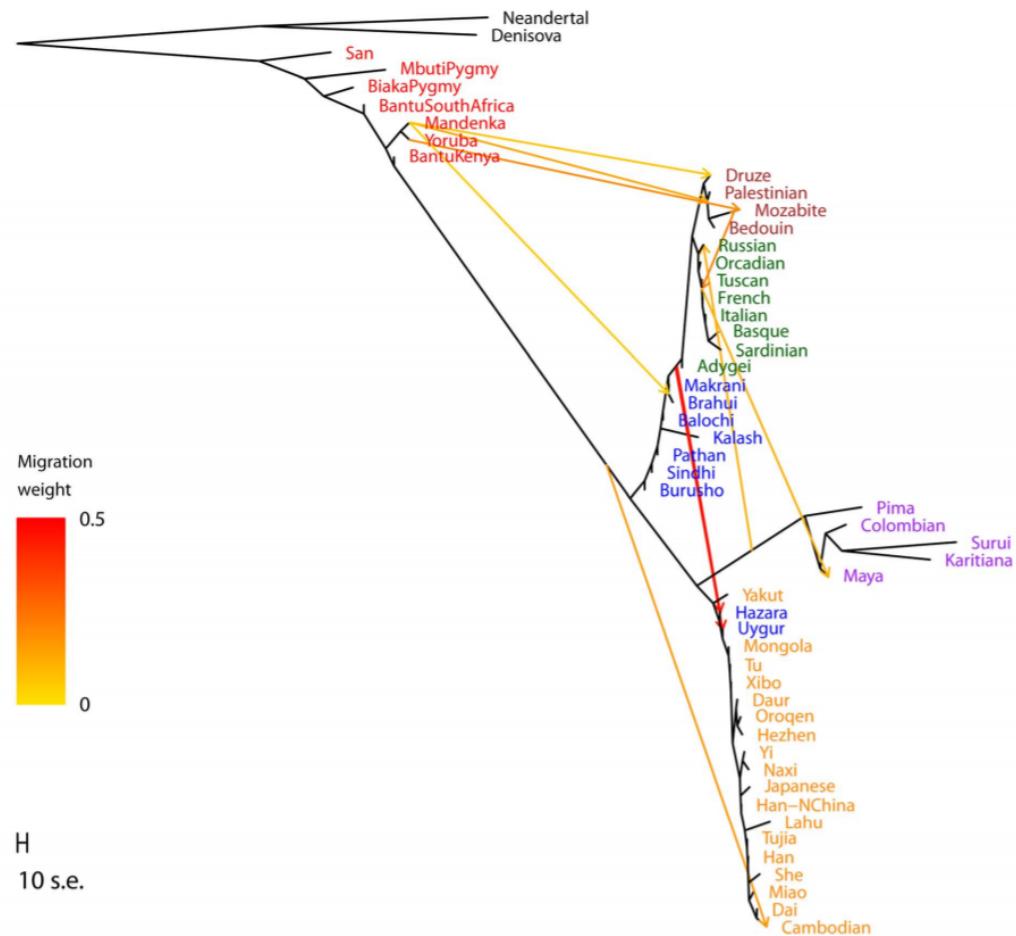
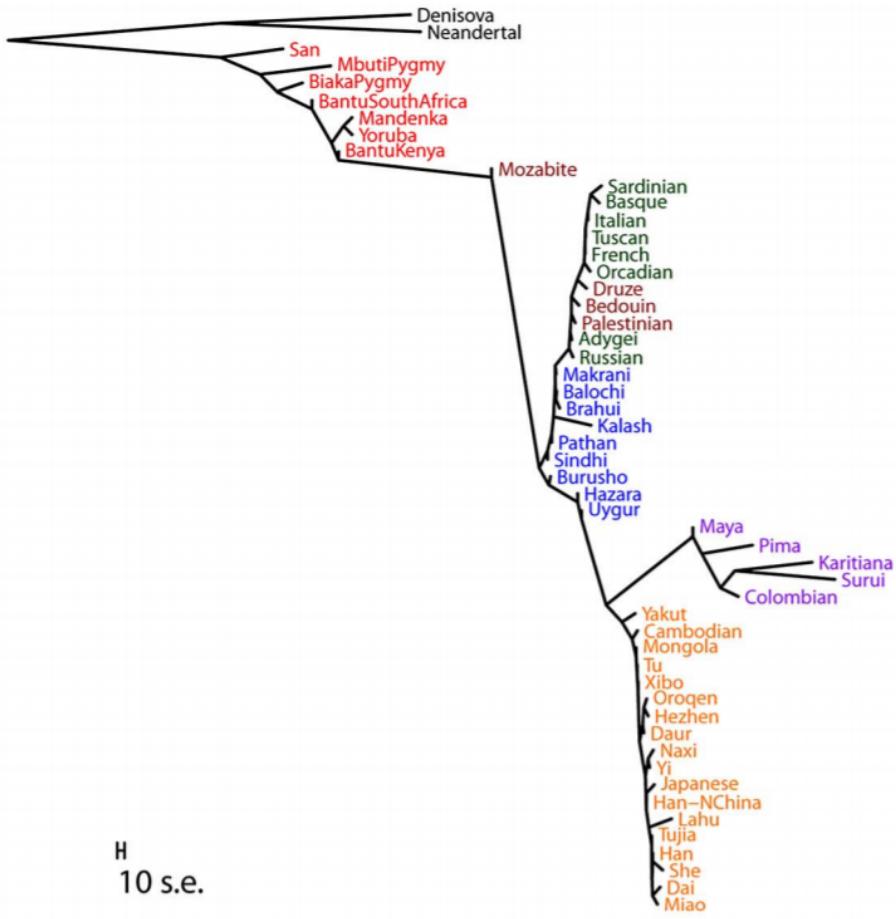
$X_1$	$c_2 + c_6$	$c_2$	0	0
$X_2$	$c_2$	$c_2 + c_5$	0	0
$X_3$	0	0	$c_1 + c_3$	$c_1$
$X_4$	0	0	$c_1$	$c_1 + c_4$
	$X_1$	$X_2$	$X_3$	$X_4$

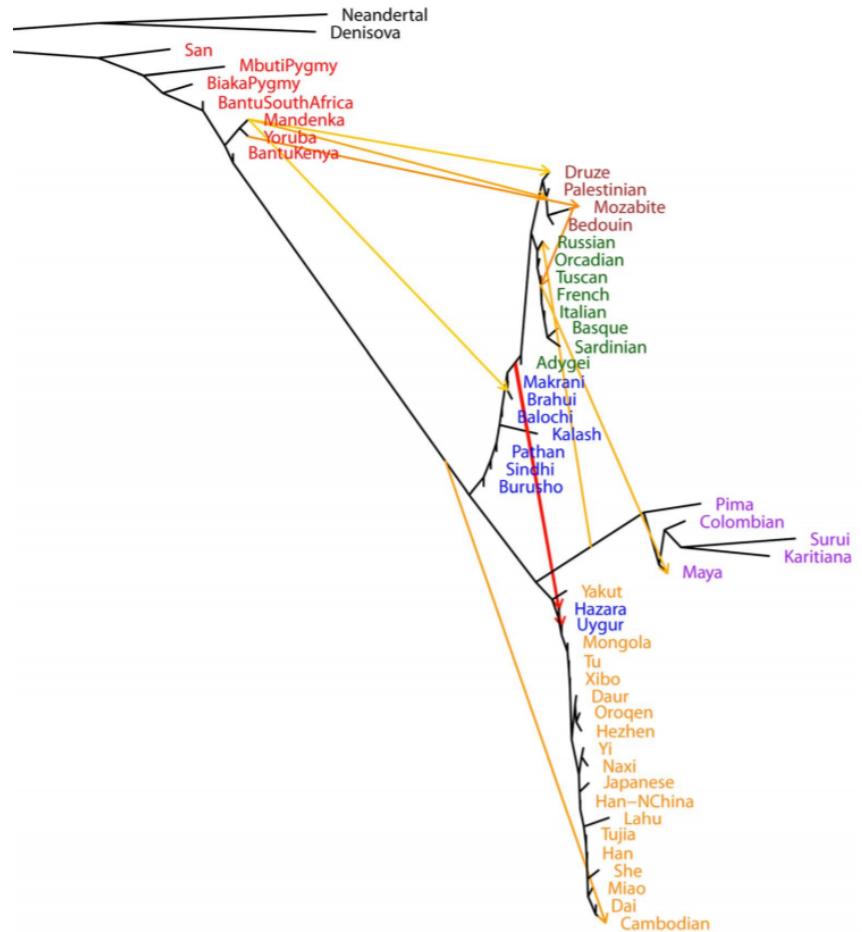
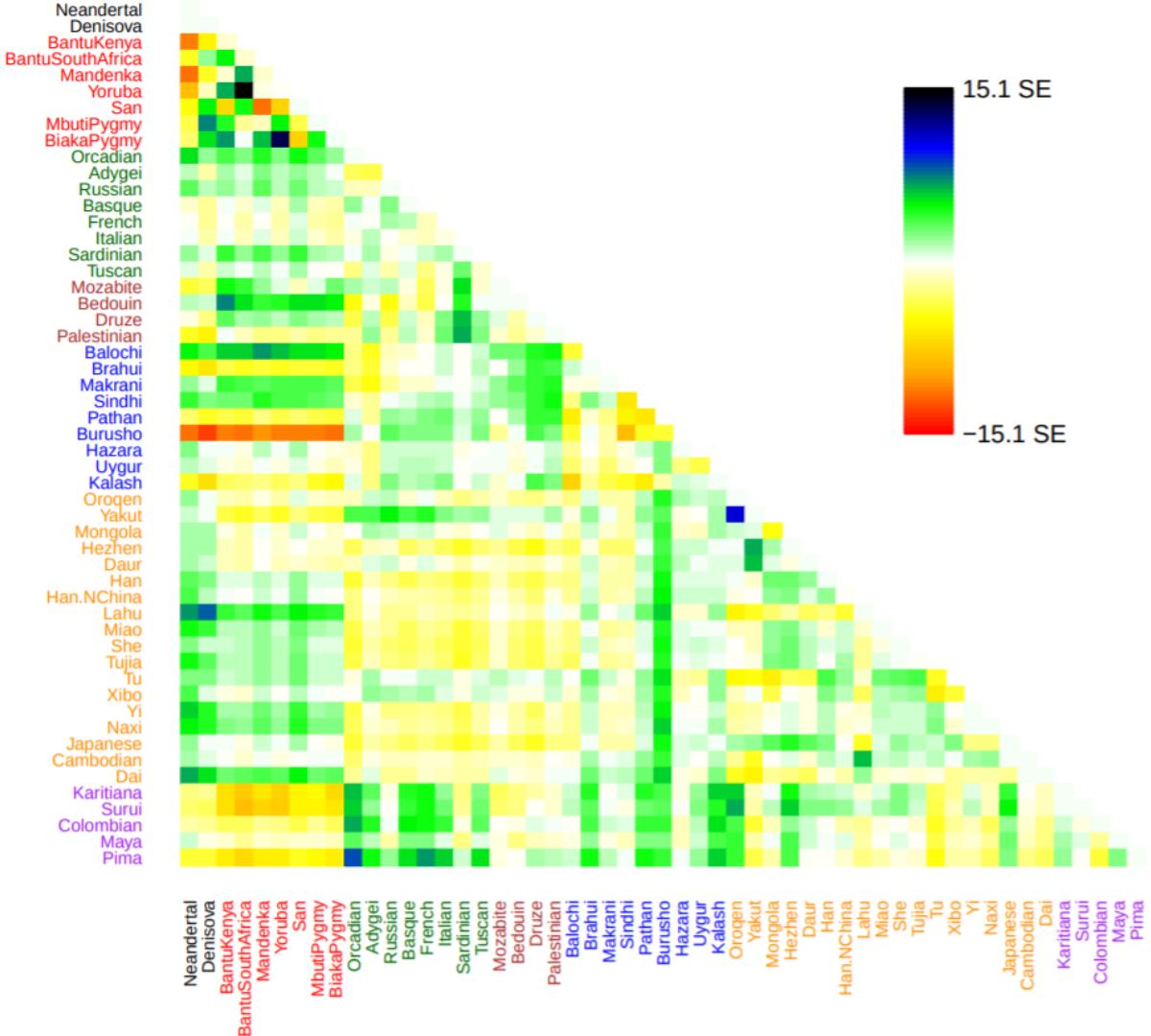
C. Example graph



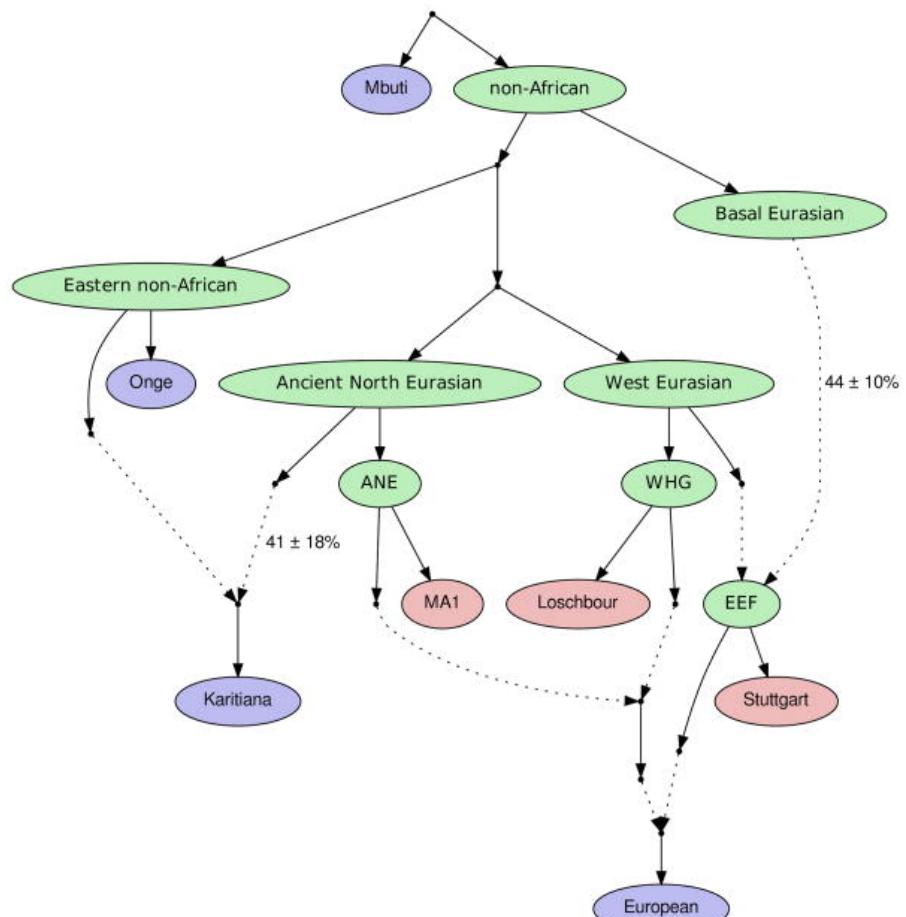
D. Covariance matrix for graph in C.

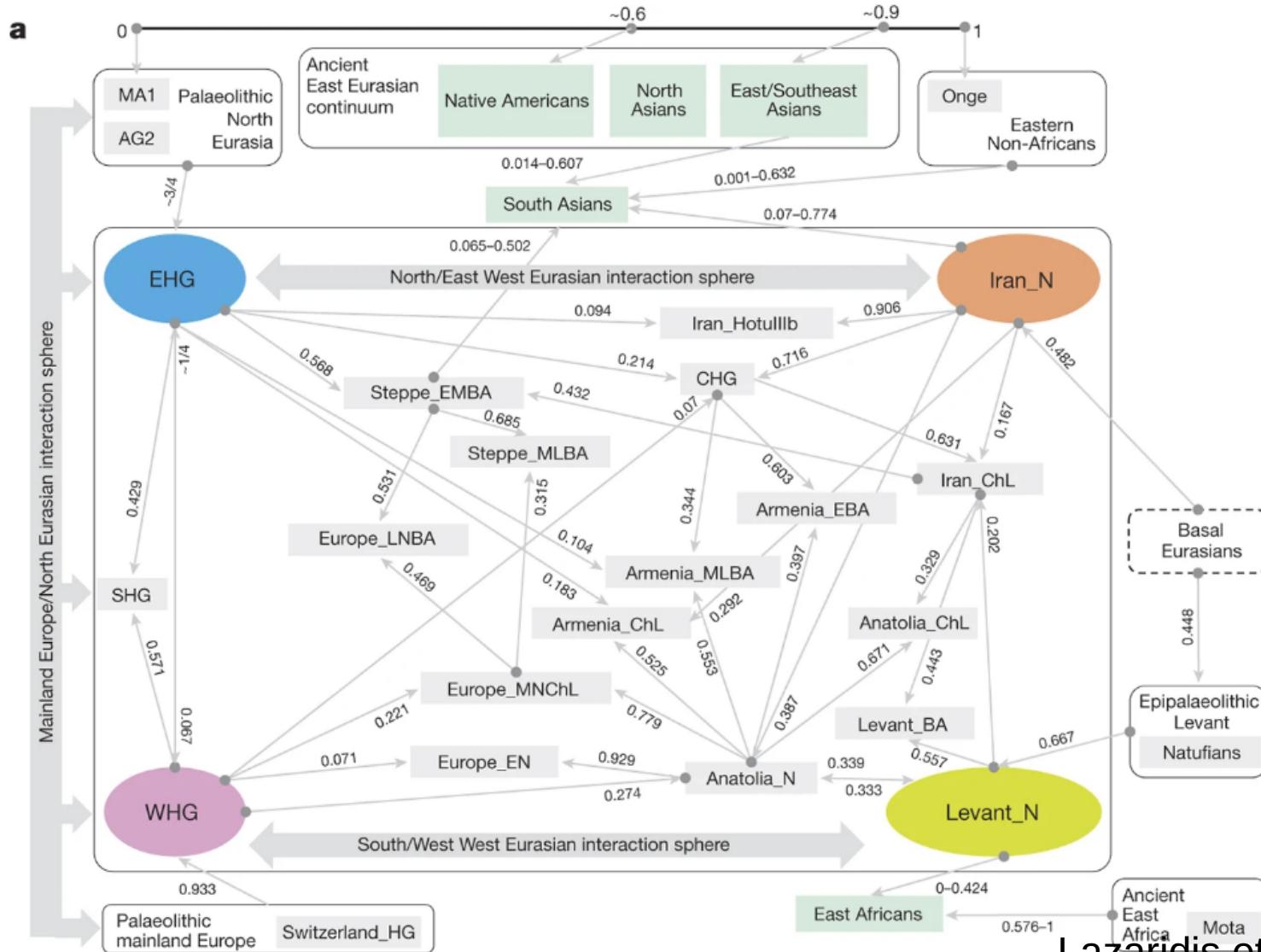
$X_1$	$c_2 + c_6$	$c_2$	$w c_2$	0
$X_2$	$c_2$	$c_2 + c_5 + c_7$	$w(c_2 + c_5)$	0
$X_3$	$w c_2$	$w(c_2 + c_5)$	$w^2(c_2 + c_5) + (1-w)^2(c_1 + c_3)$	$(1-w)c_1$
$X_4$	0	0	$(1-w)c_1$	$c_1 + c_4$
	$X_1$	$X_2$	$X_3$	$X_4$





# Admixture graphs



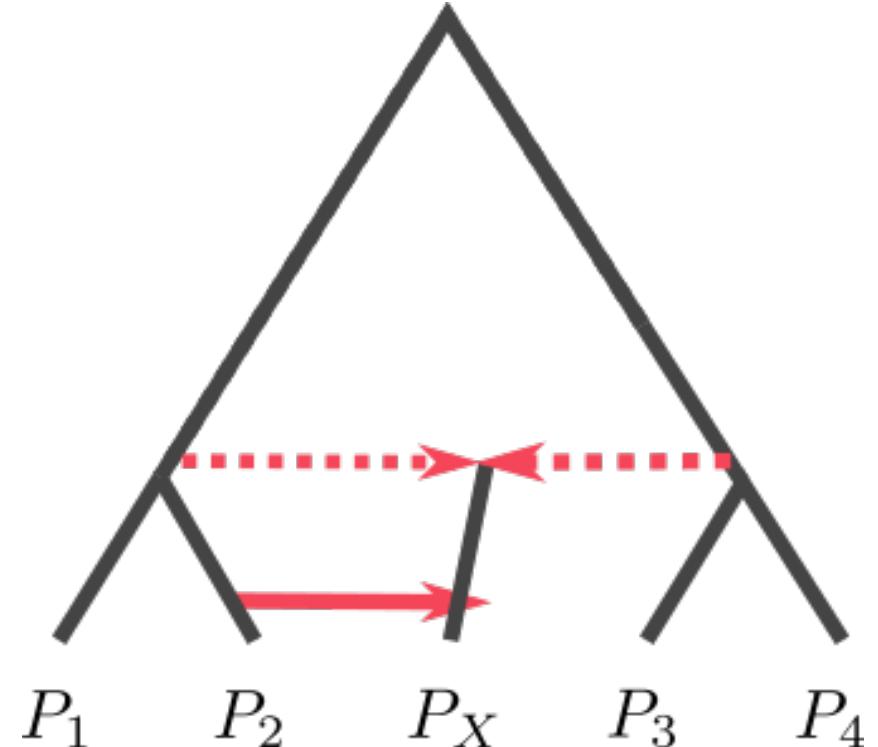


# Practical Considerations: Which approach should I use?

- Admixture
- PCA
- Trees / Admixture Graph
- All of the above?

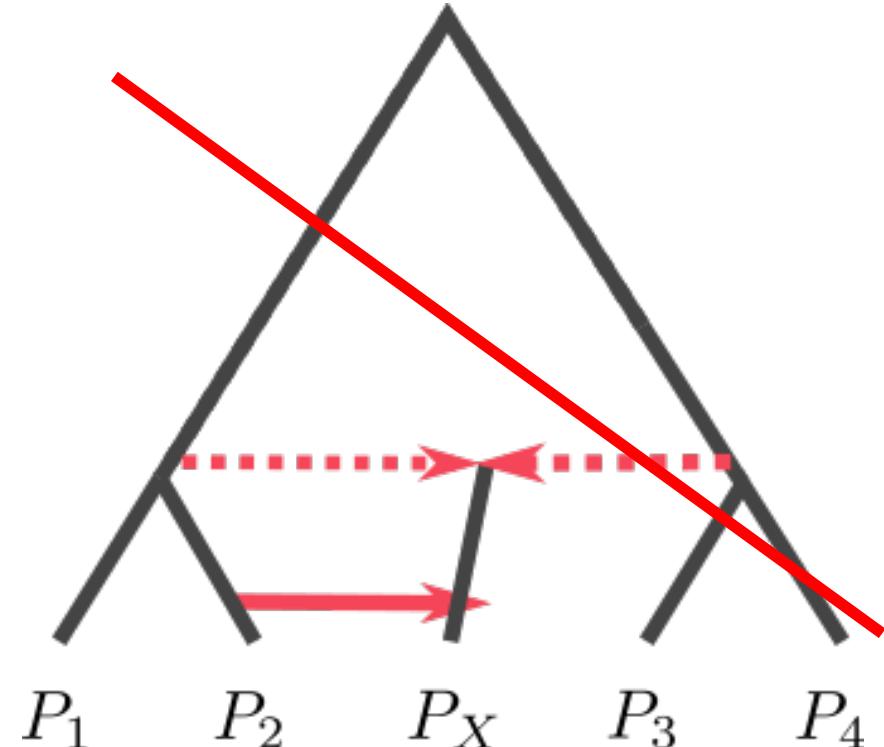
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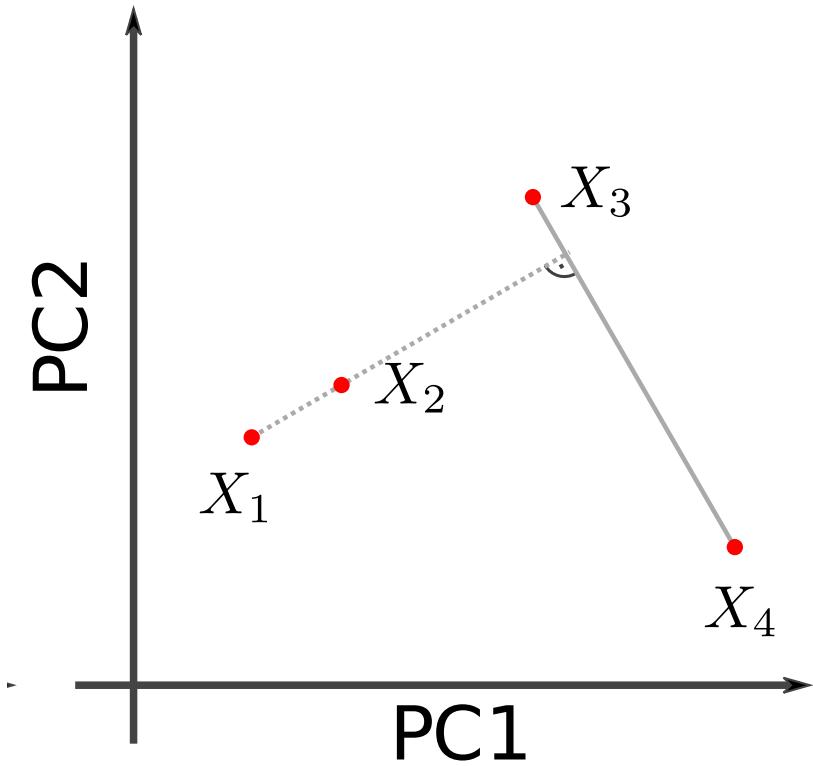
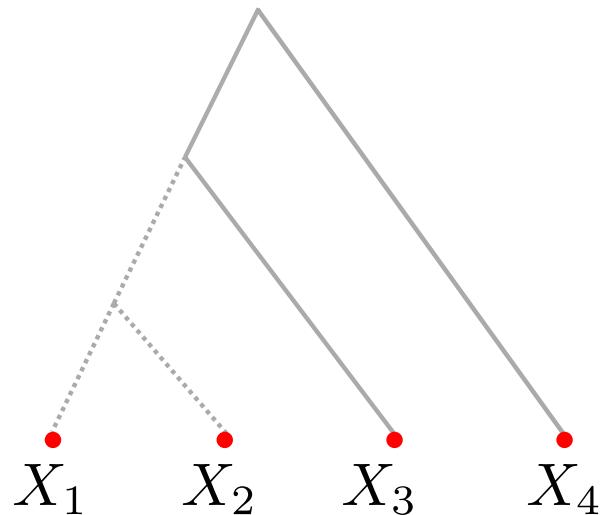
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- Admixture
- PCA
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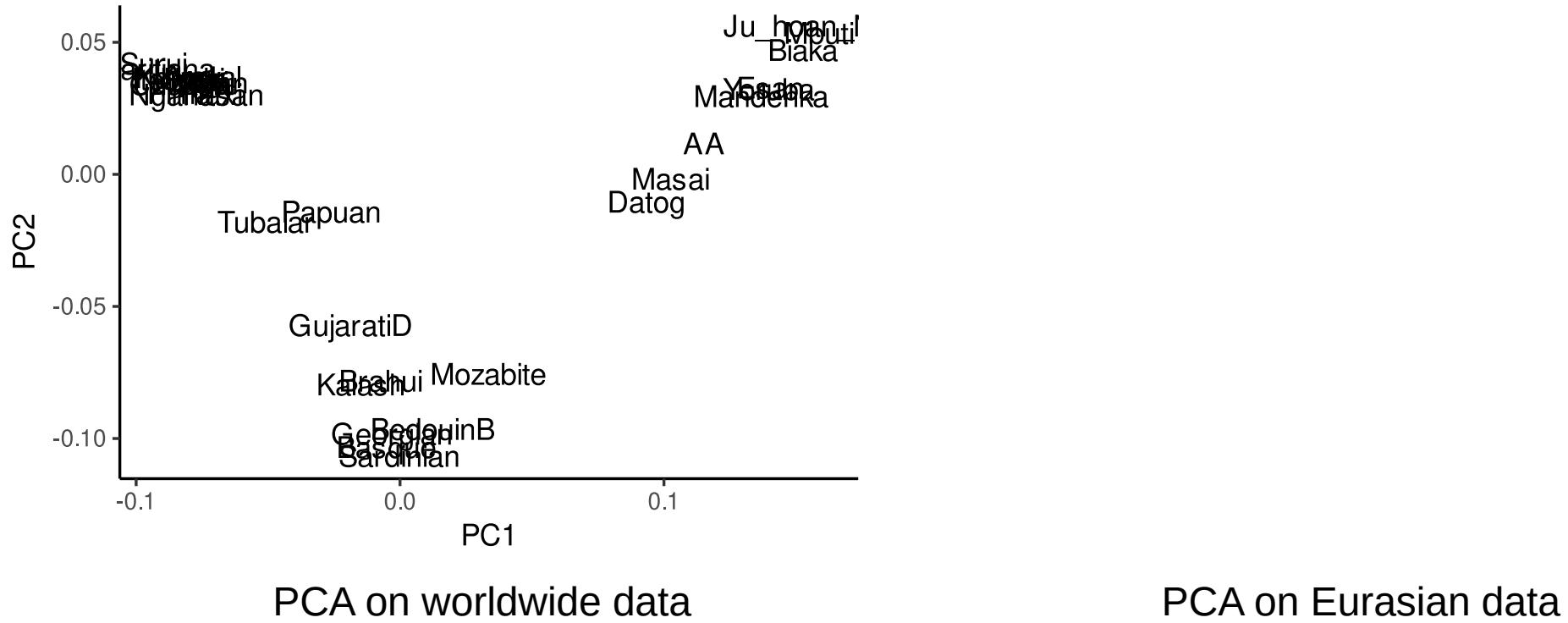


# Trees vs PCA

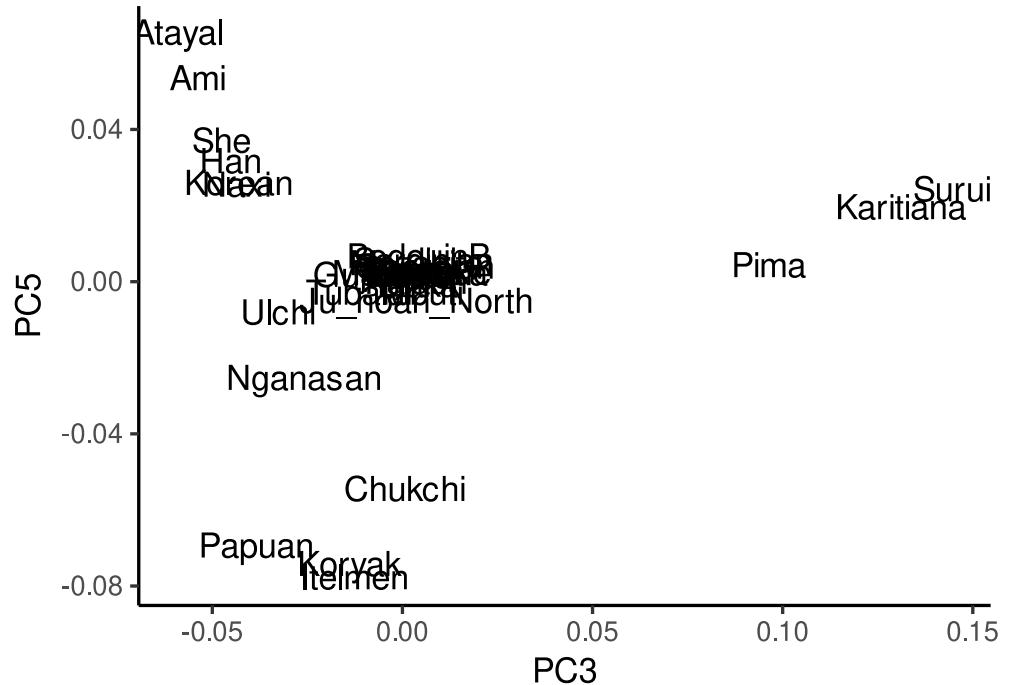
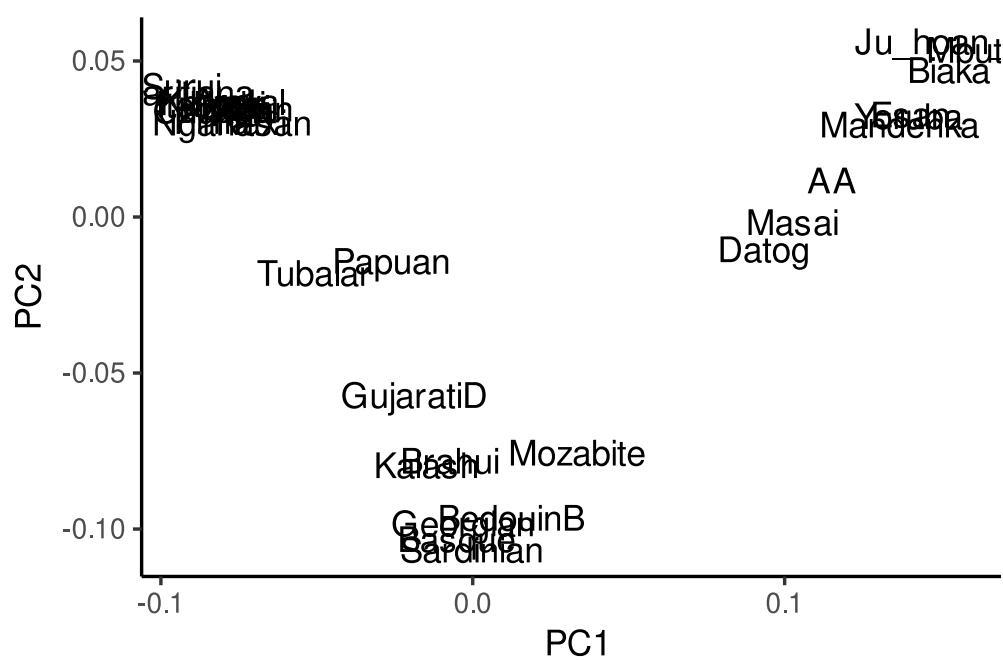
$$F_4(X_1, X_2; X_3, X_4)$$



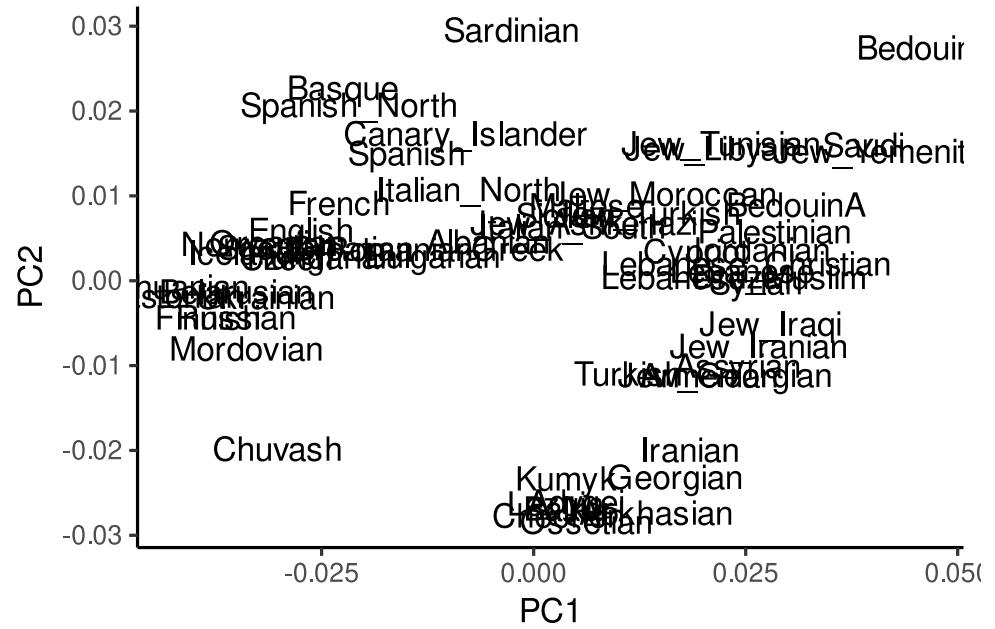
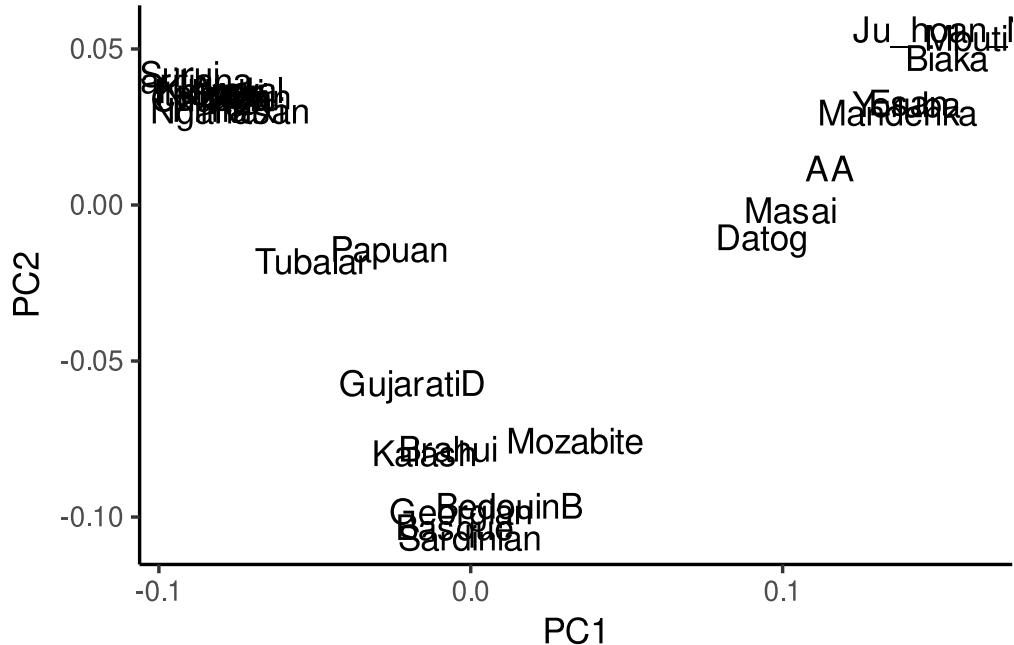
# Trees vs PCA



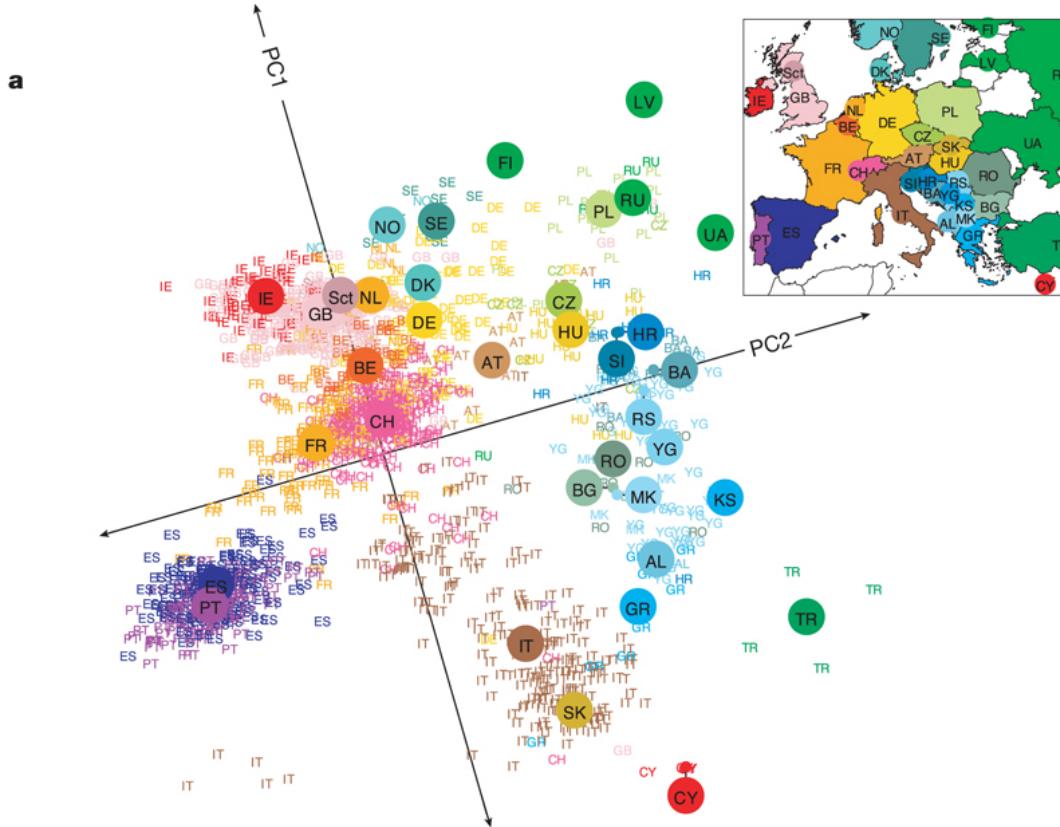
# Trees vs PCA



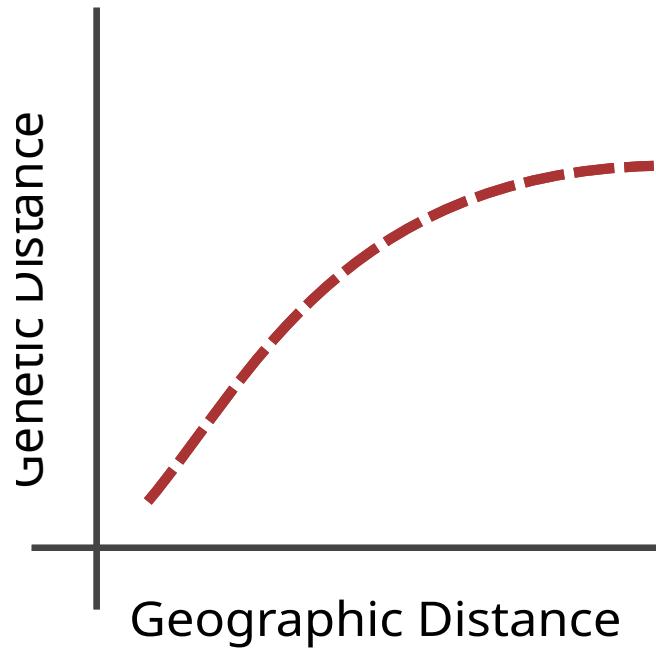
# Trees vs PCA



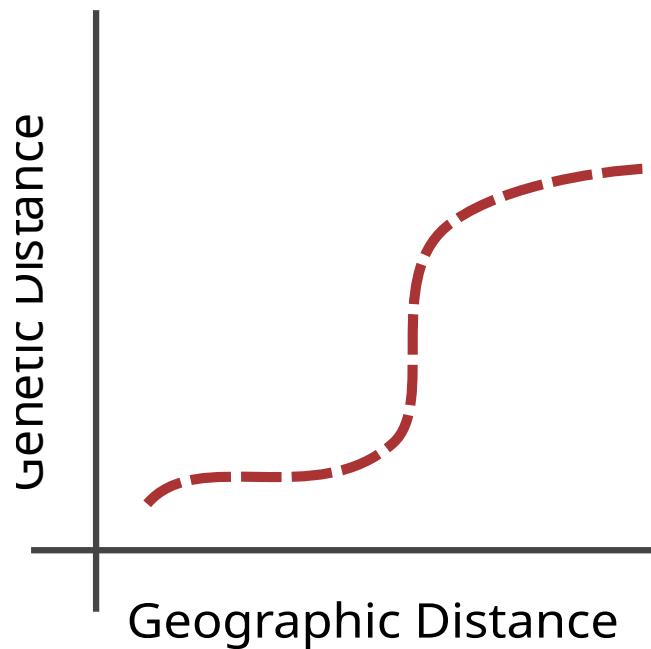
# Many other possibilities



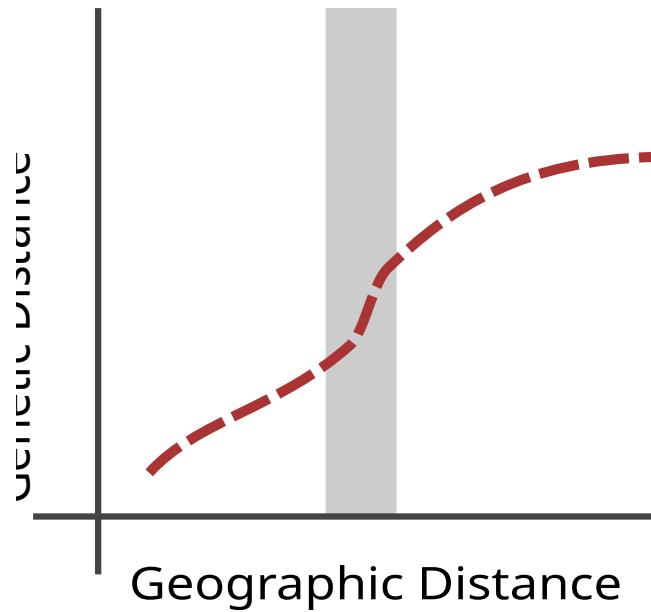
# Spatial structure



# Discrete structure



# Inferring discontinuities

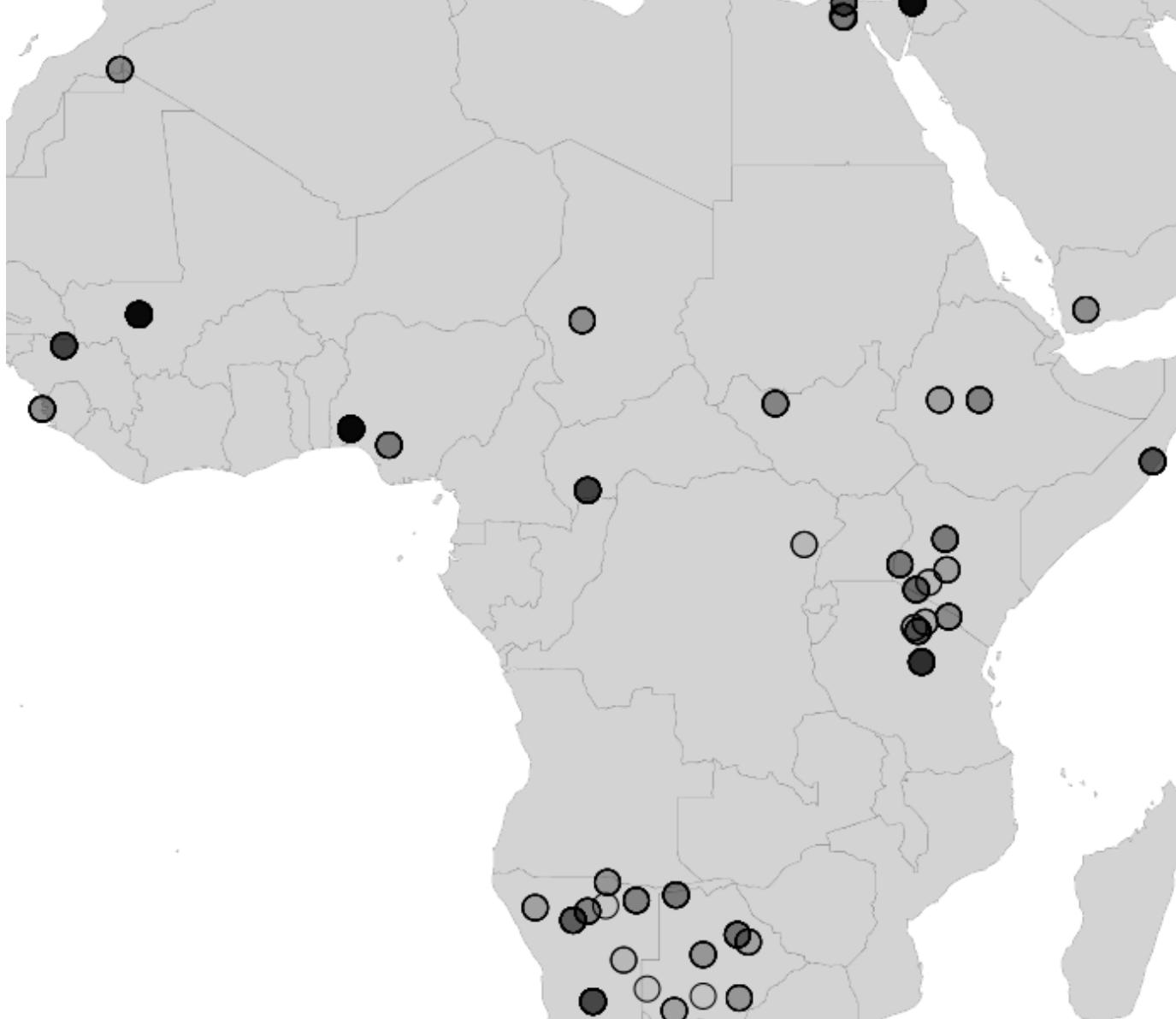


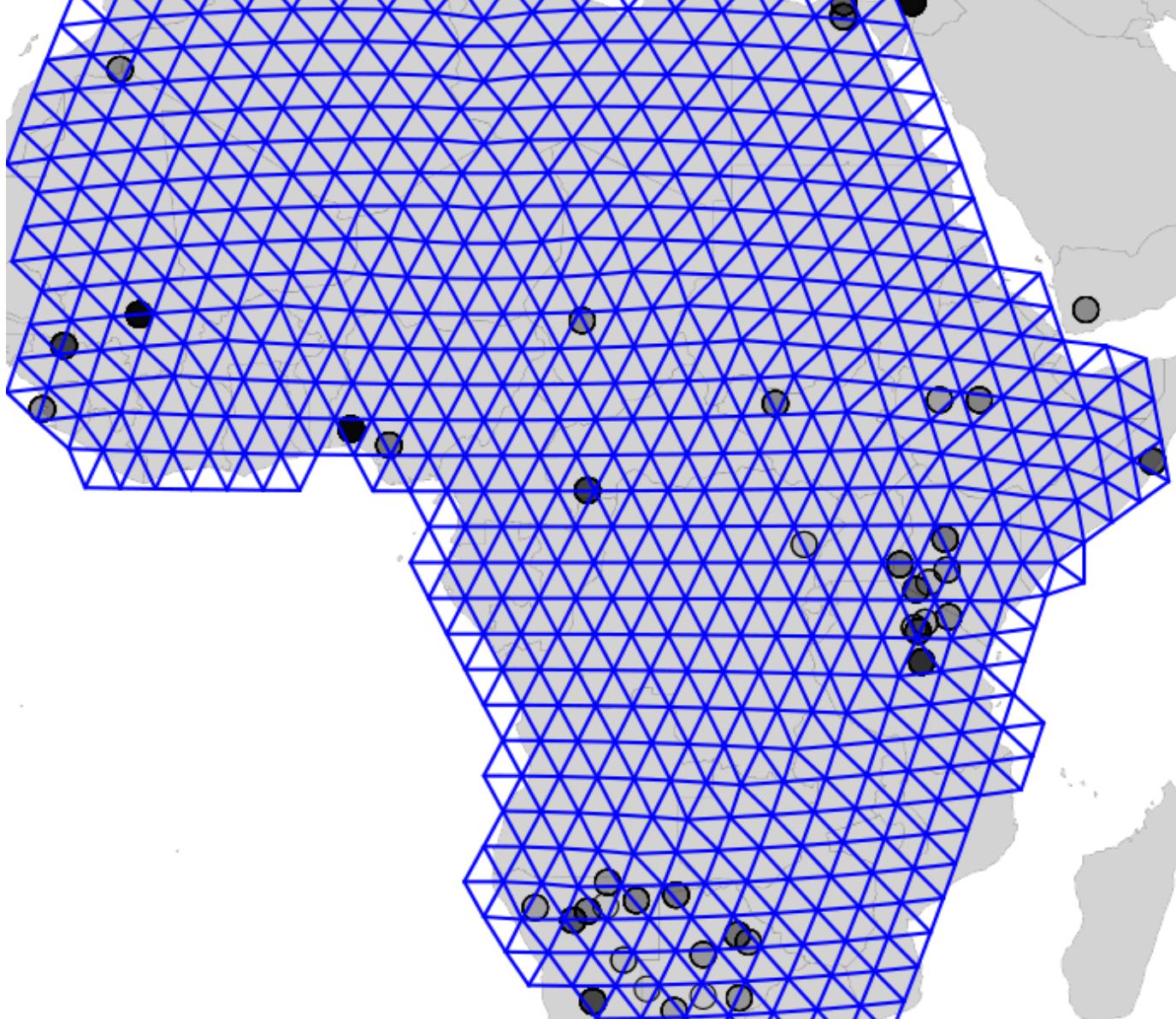
# EEMS: Estimating Effective Migration Surfaces

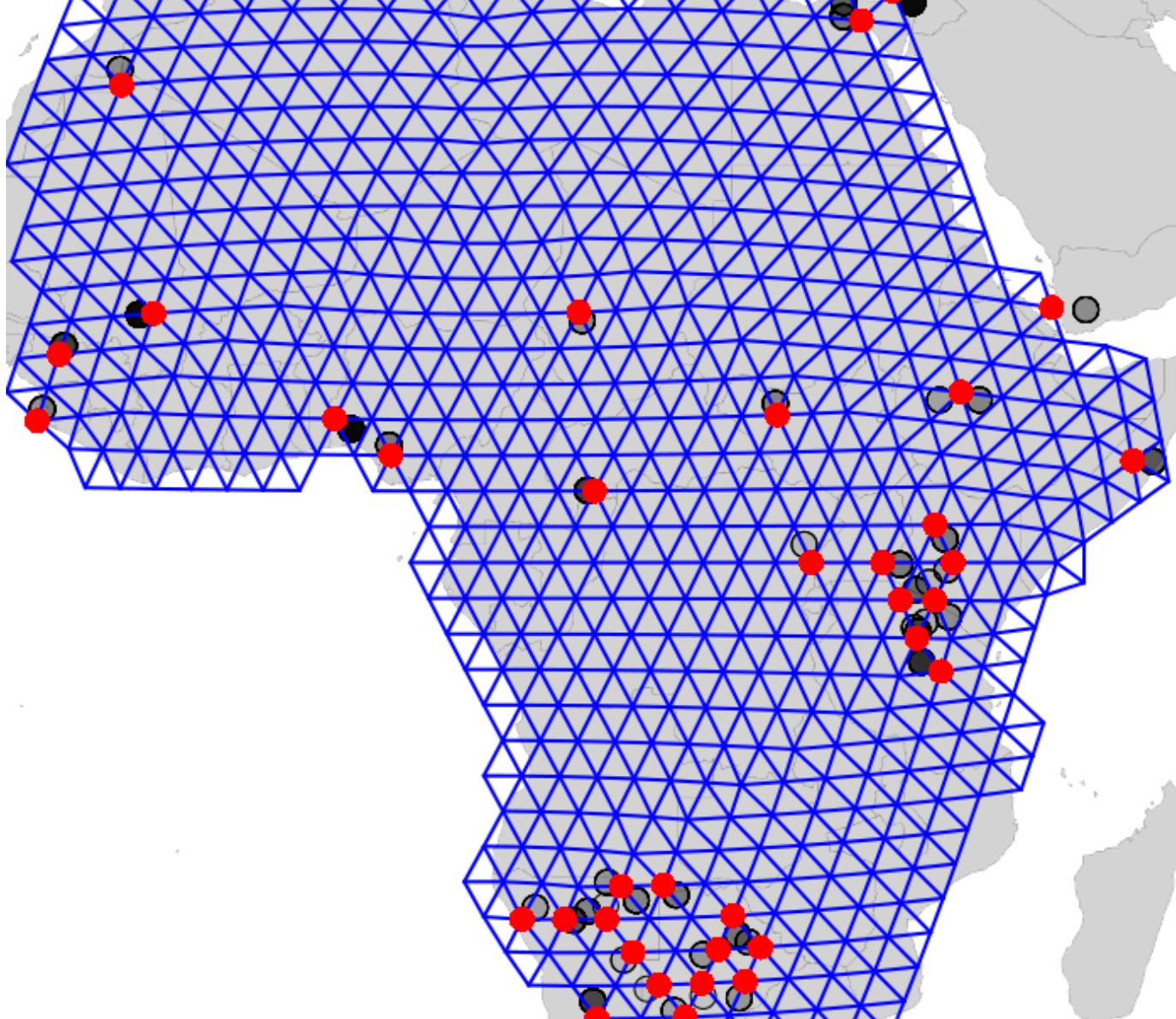
- Petkova, Novembre & Stephens (2016)

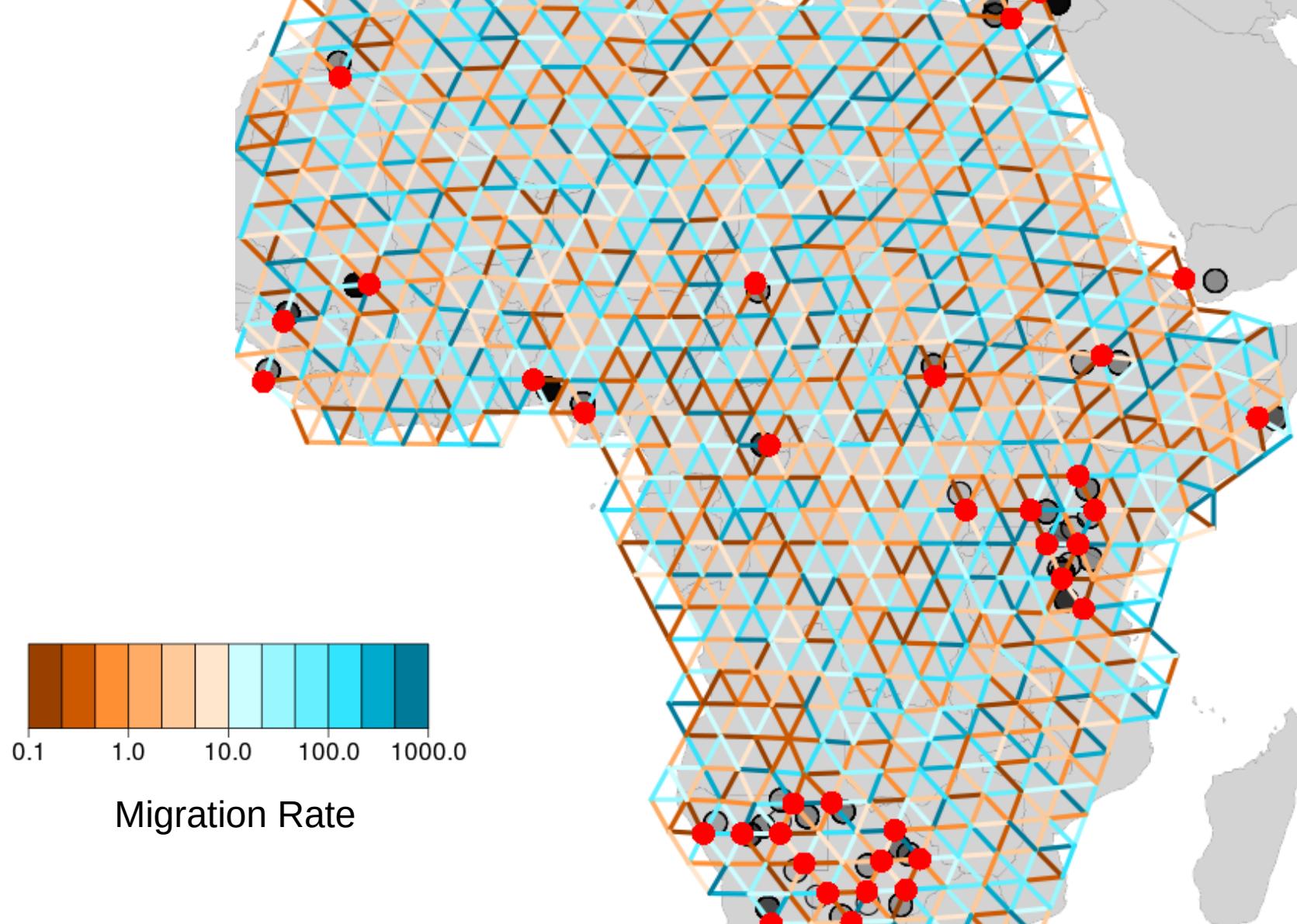


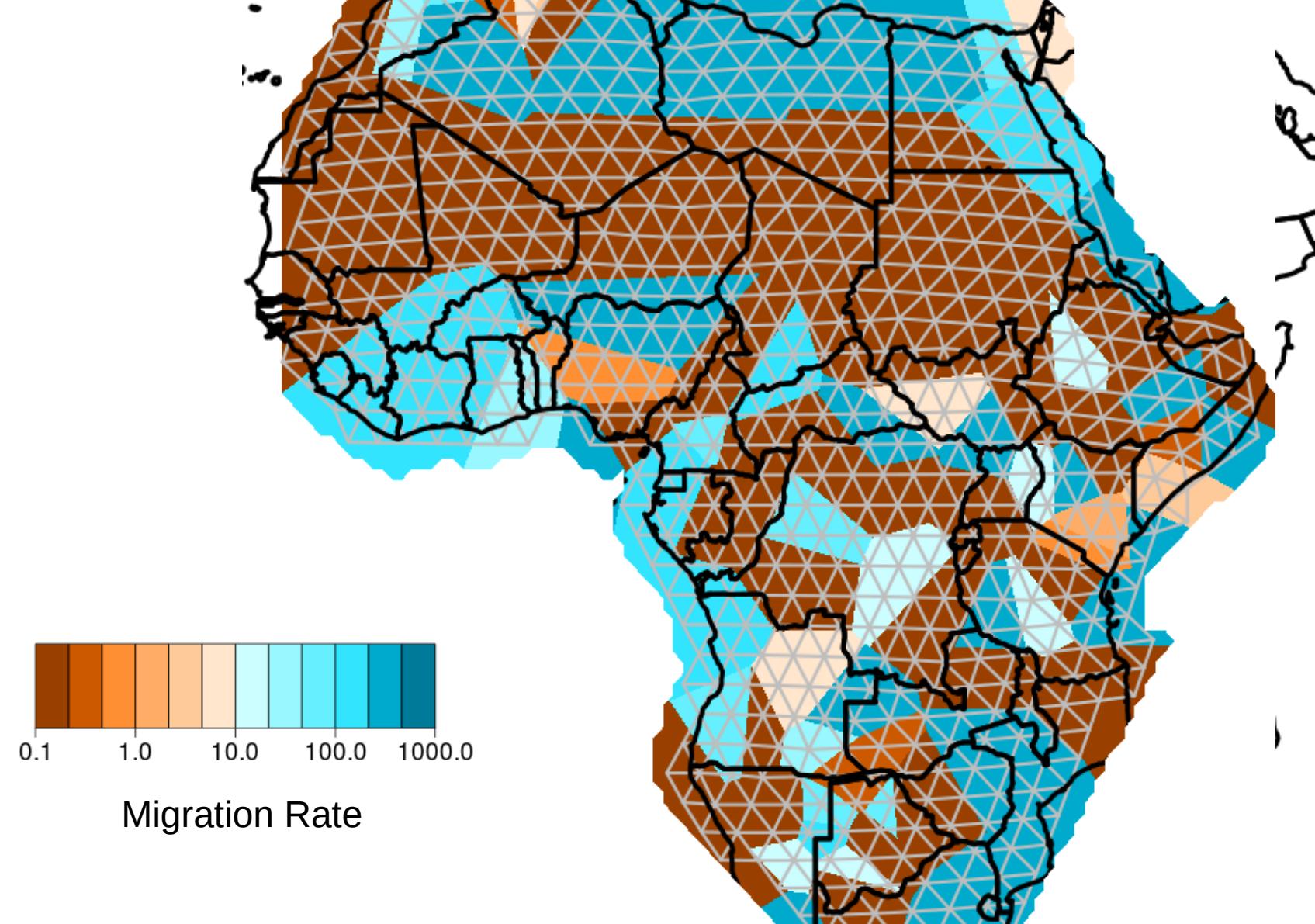


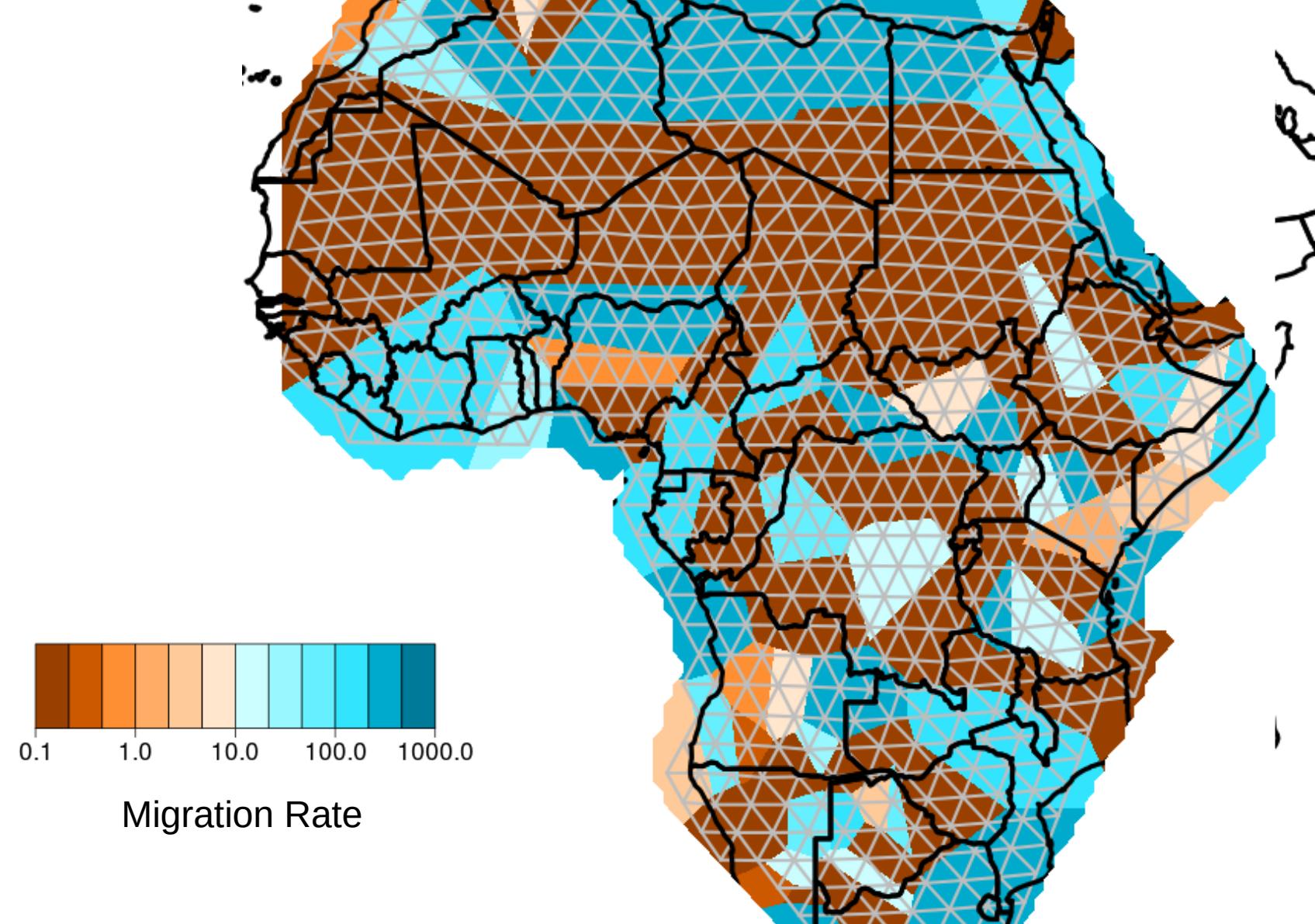


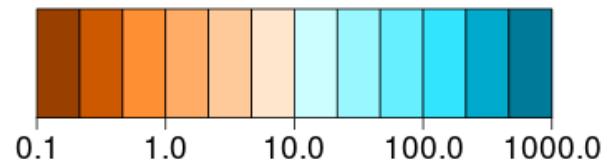
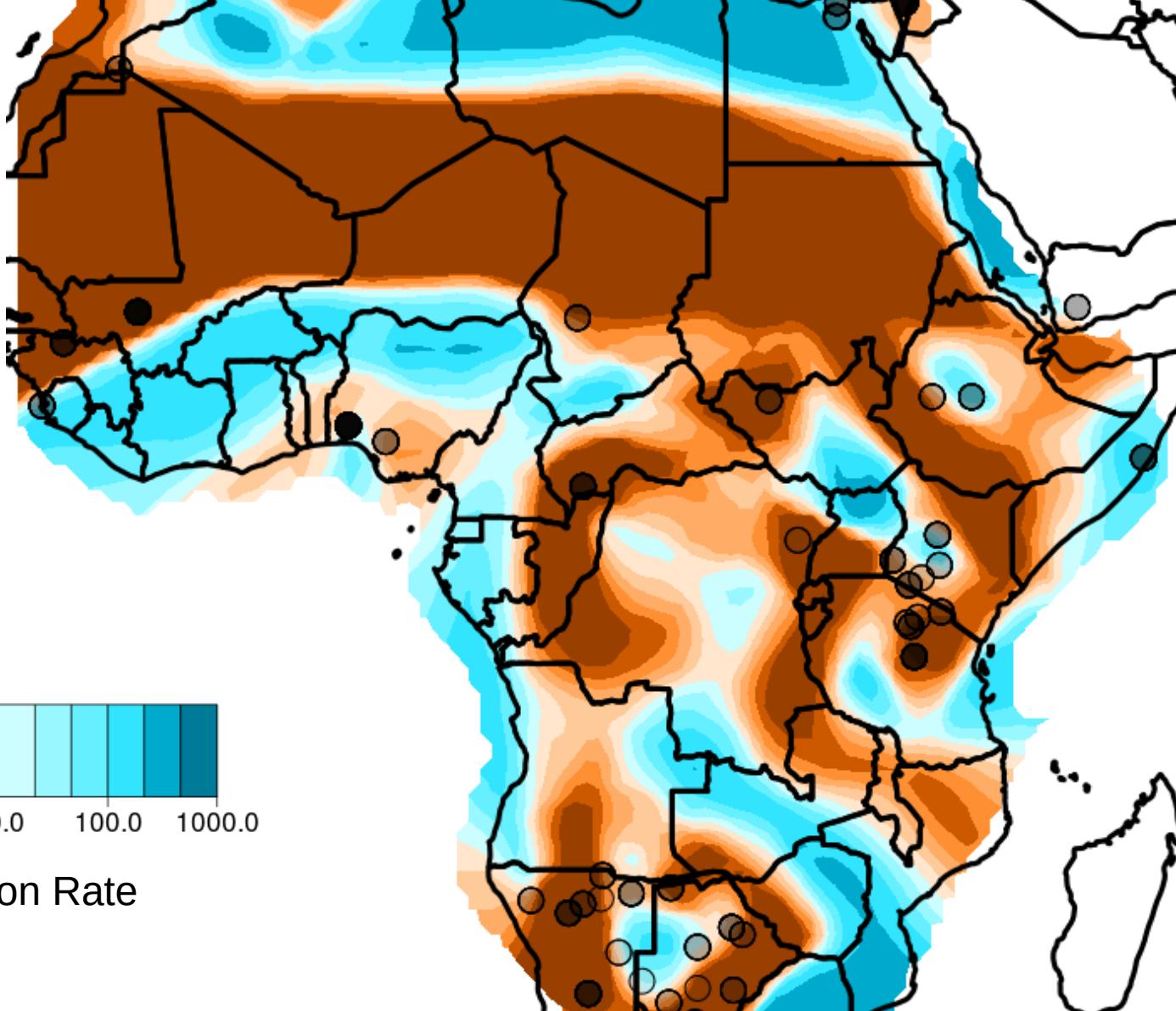




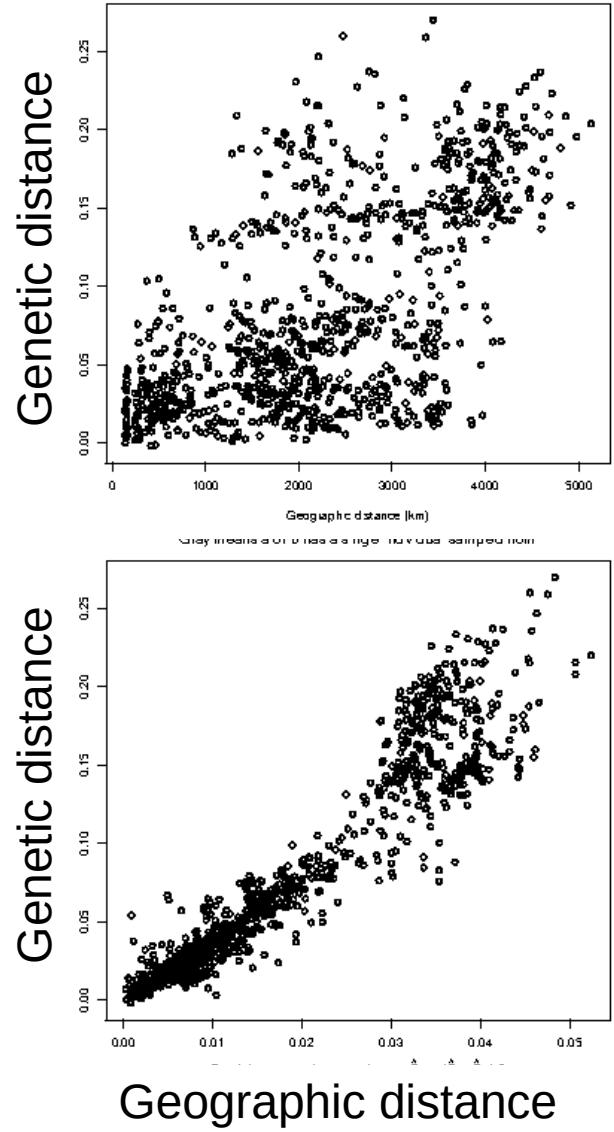
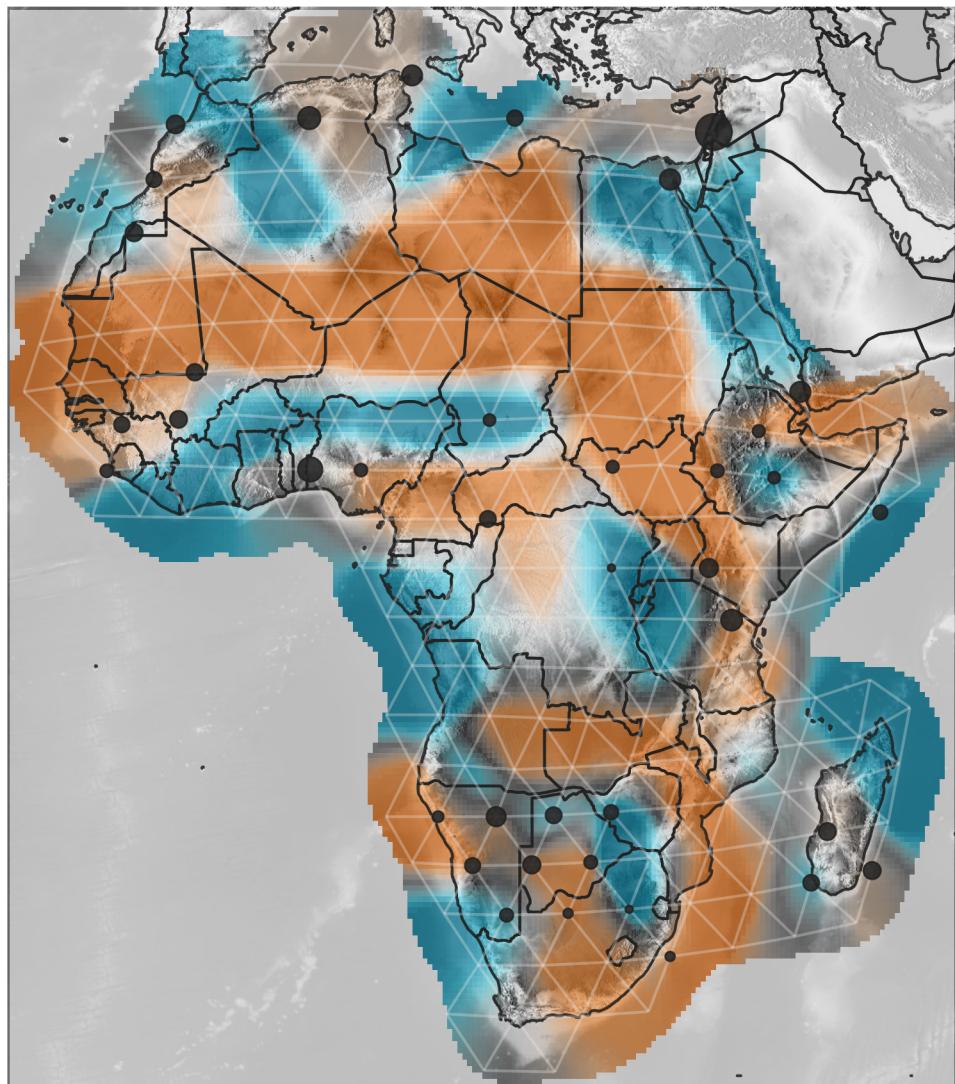




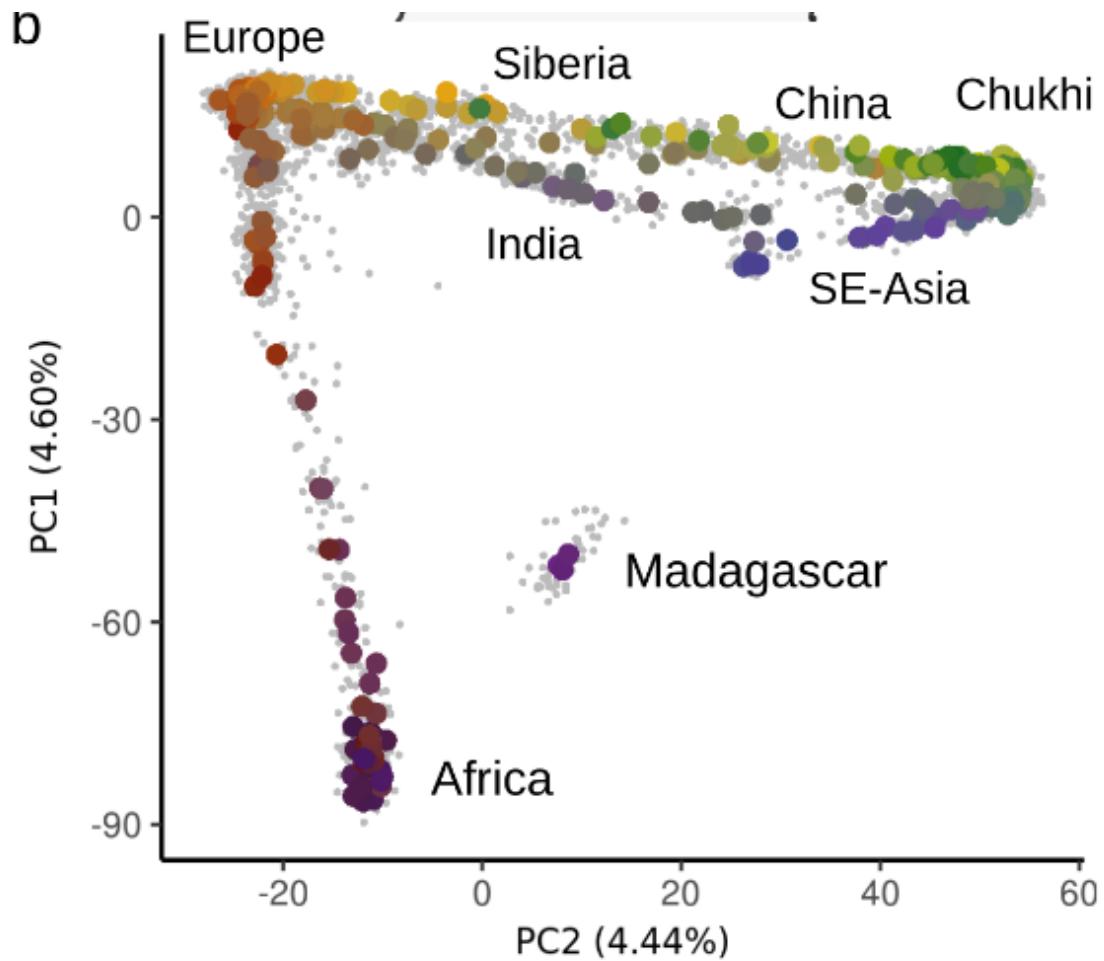
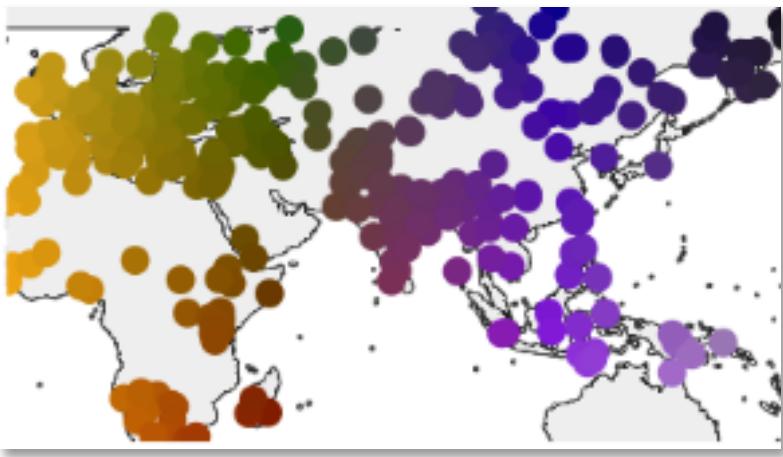


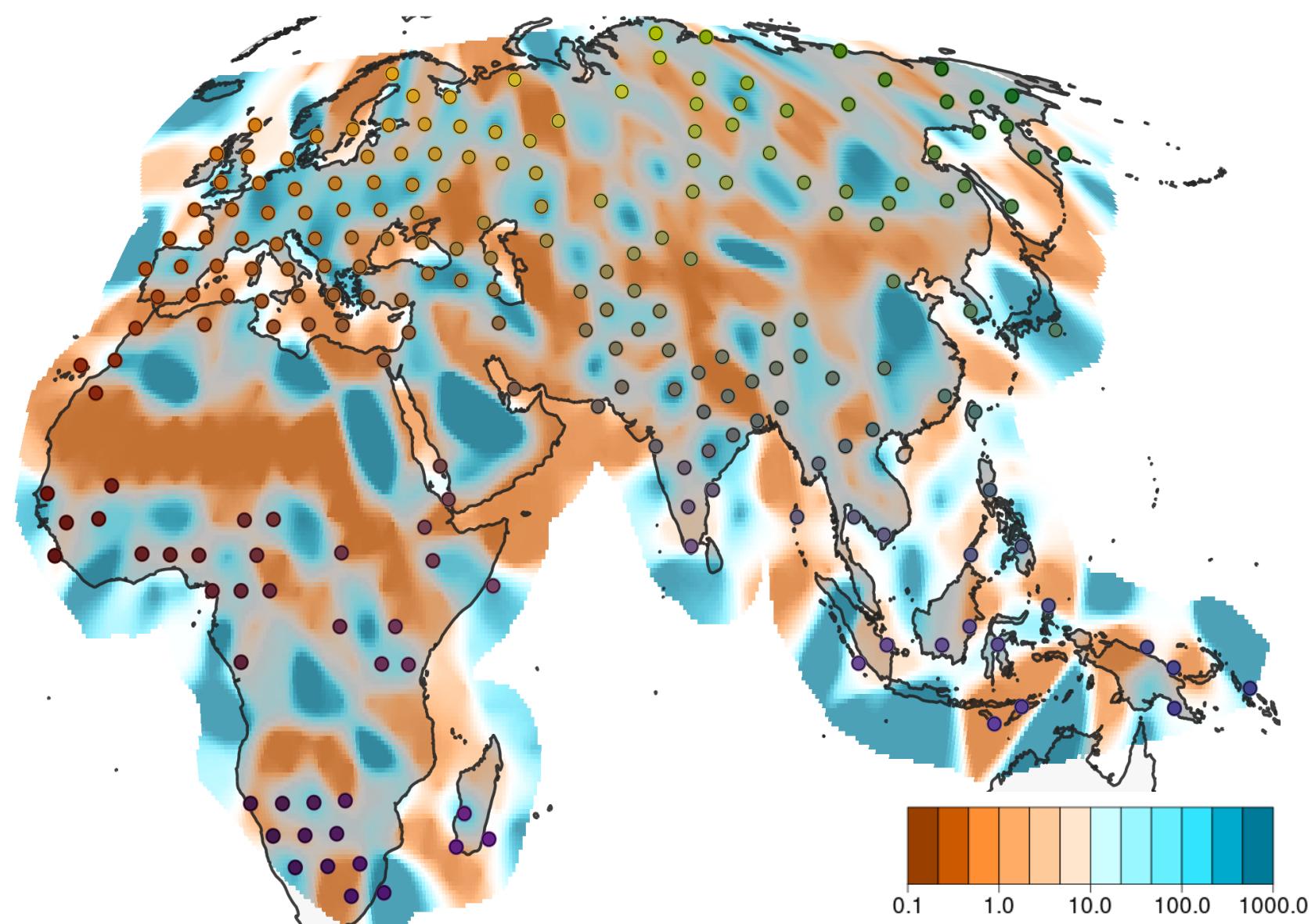


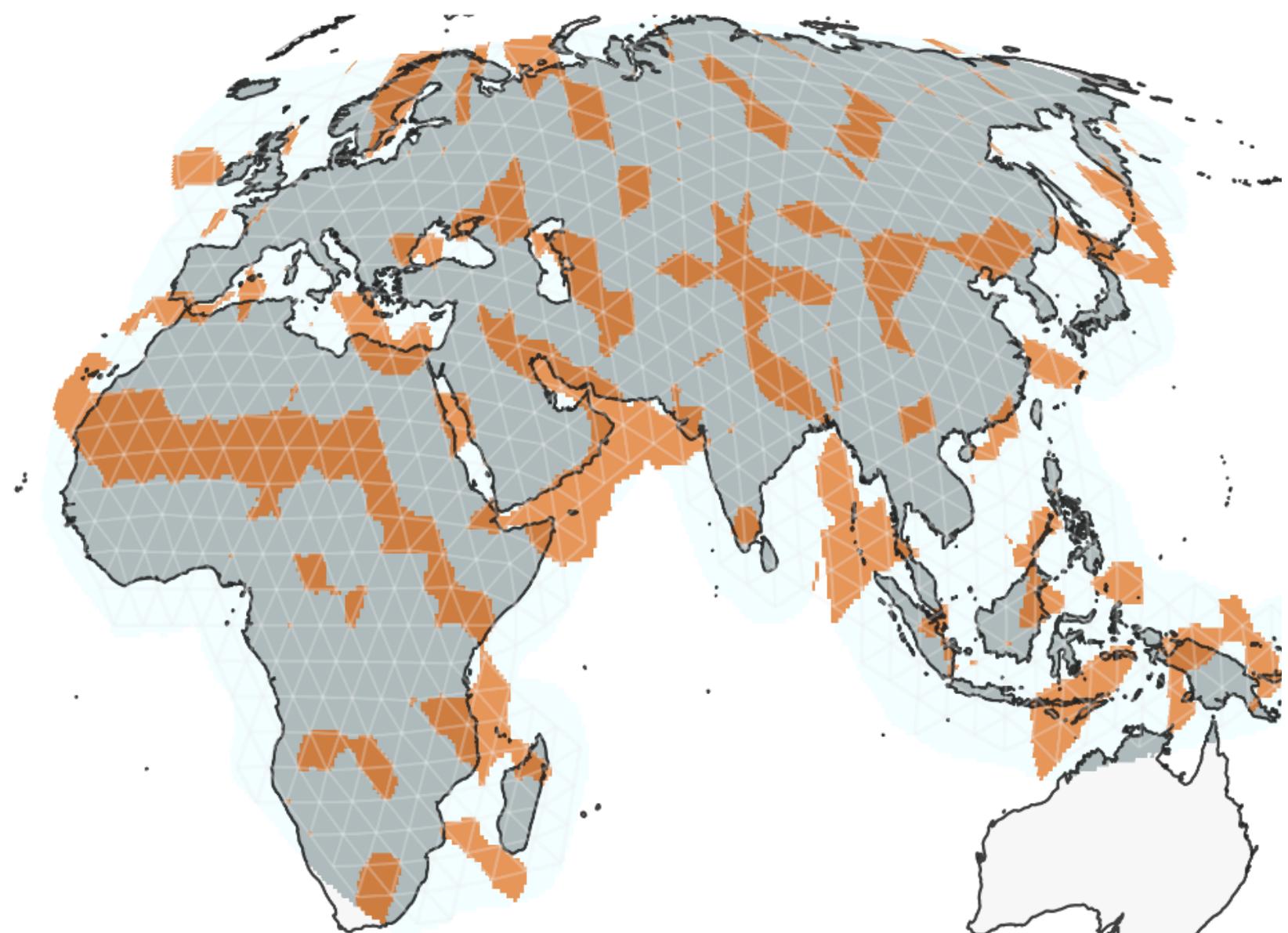
Migration Rate

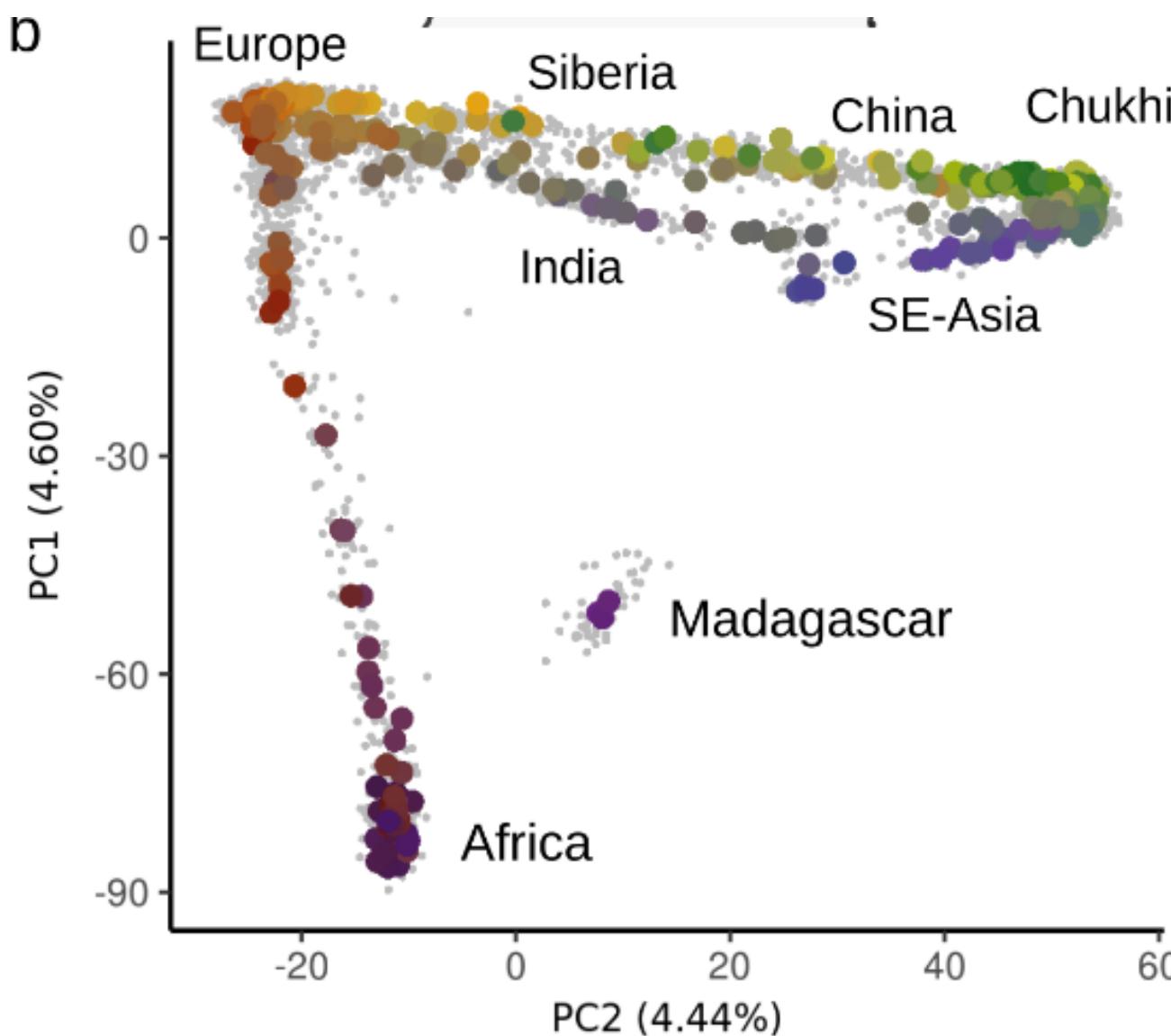


# Example









# When should we use trees/admixture graphs?

## Trees / Admixture graph

- Sparse structure / sampling
- Hierarchical structure
- Large time scales

## Spatial/continuous models

- High-density sampling
- Small time scales
- Continuous structure