Comparative method, coalescents, and the future

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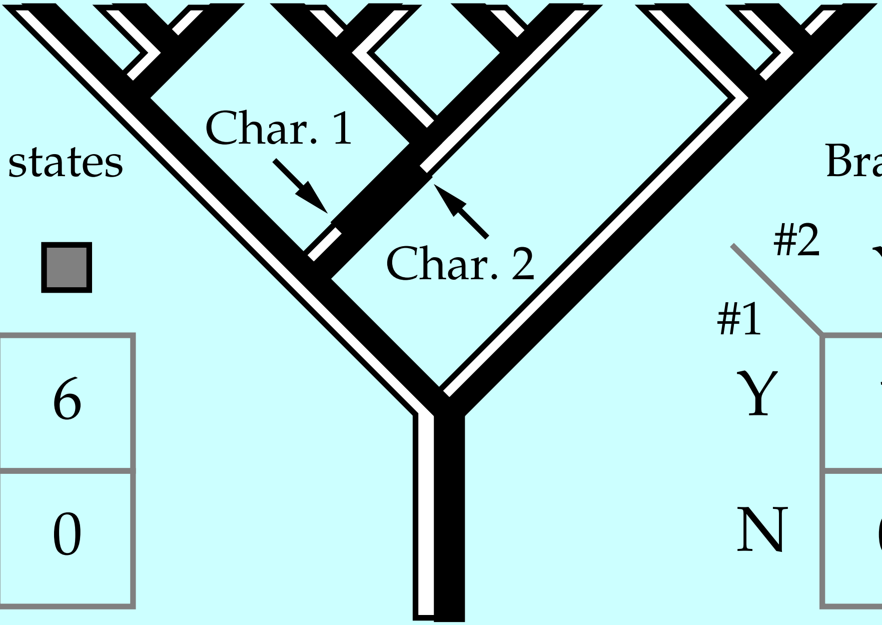
Correlation of states in a discrete-state model

Character 1: □ □ □ ■ ■ ■ ■ □ □ □

Character 2: ■ ■ ■ □ □ □ □ ■ ■ ■



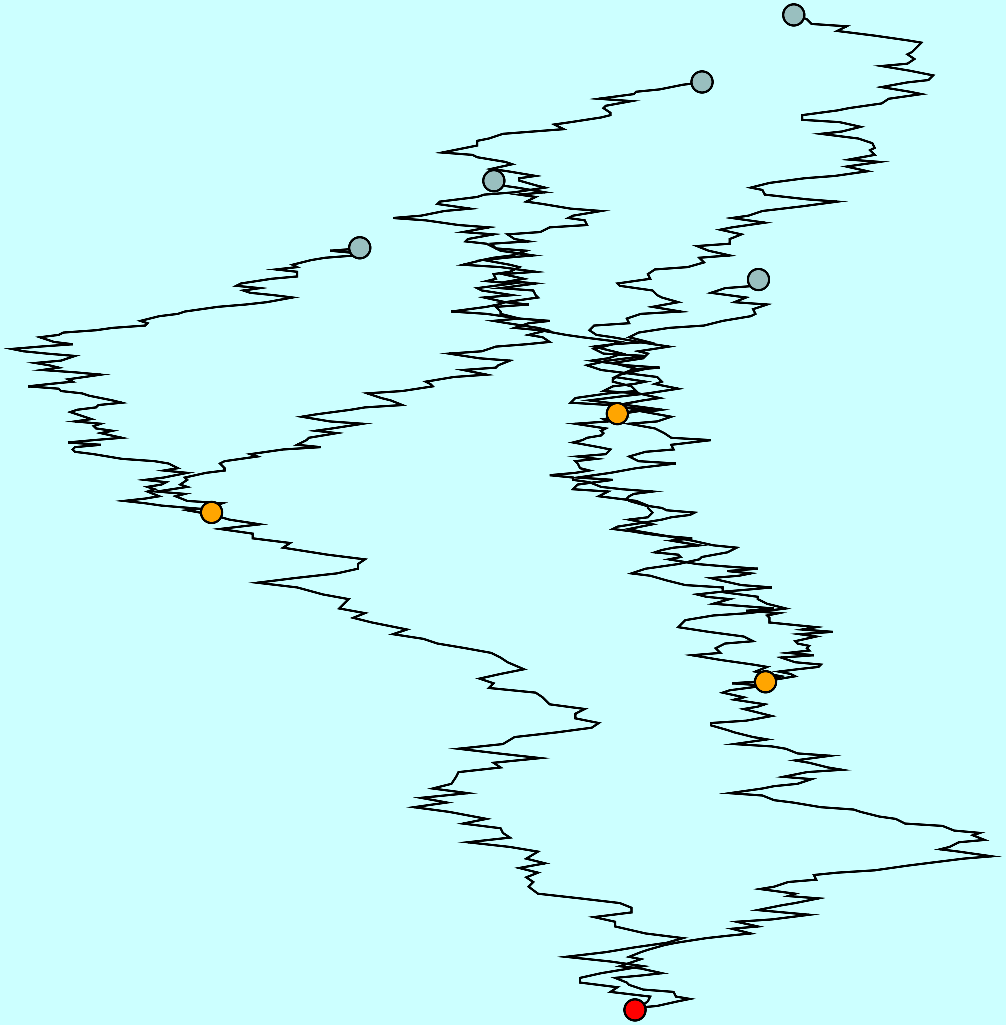
Species states

#2 #1	□	■
□	0	6
■	4	0

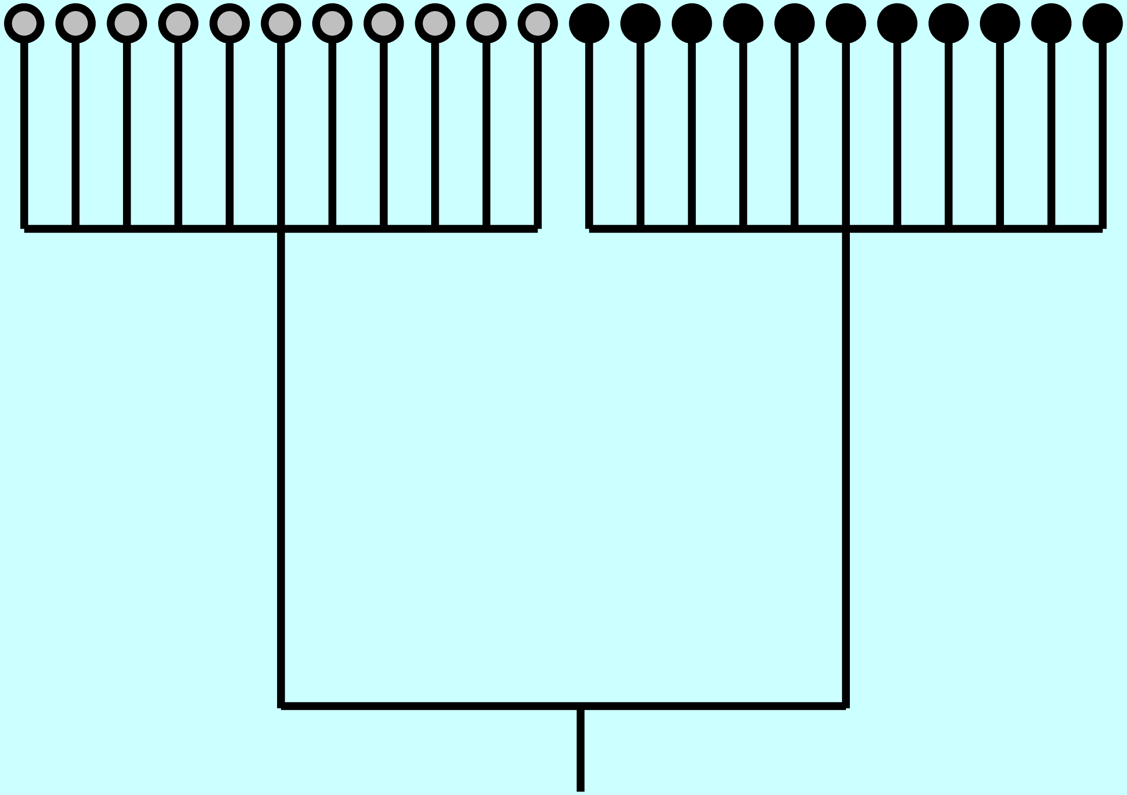
Branch changes

#2 #1	Y	N
Y	1	0
N	0	18

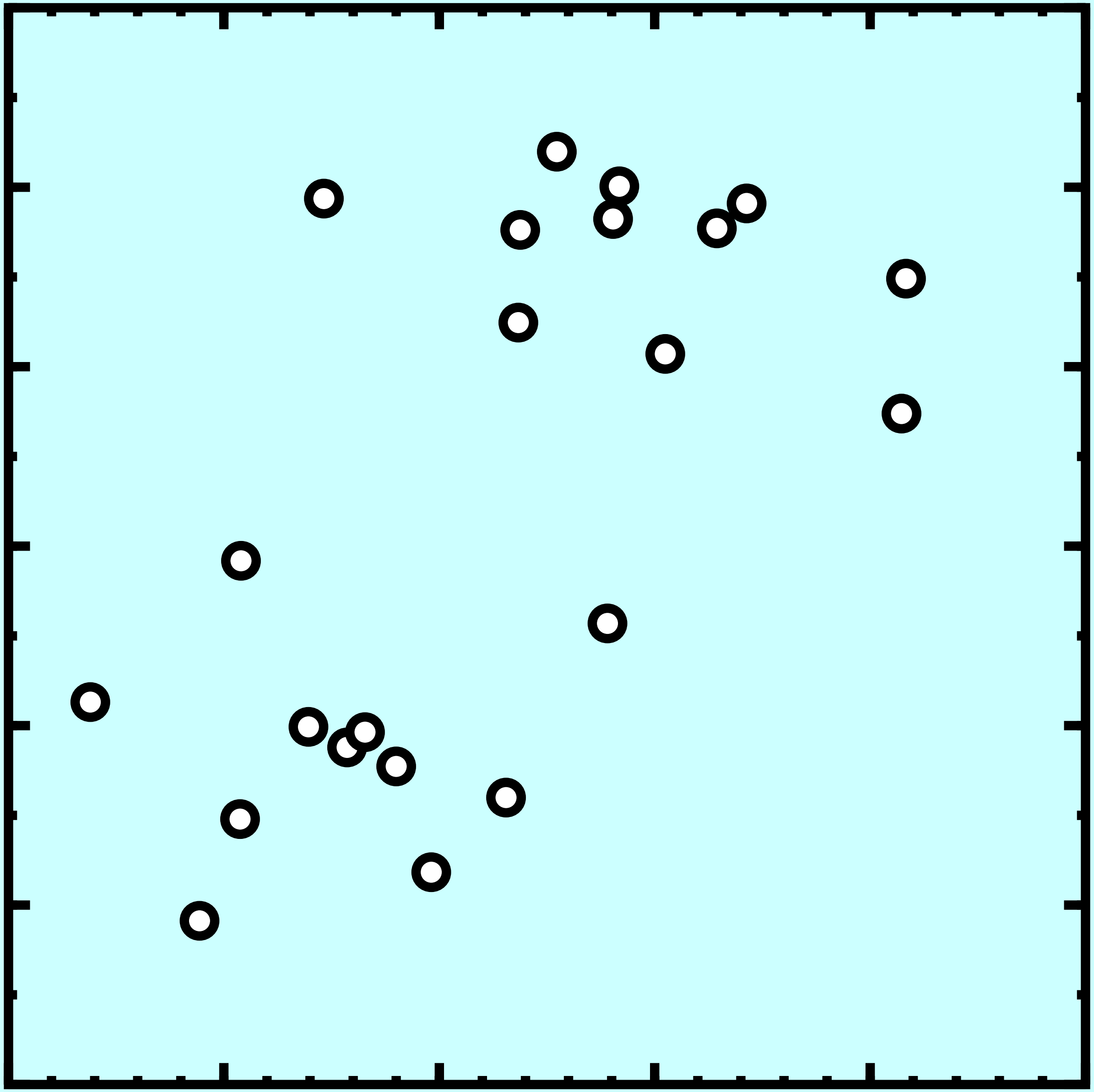
A simple model: Brownian motion



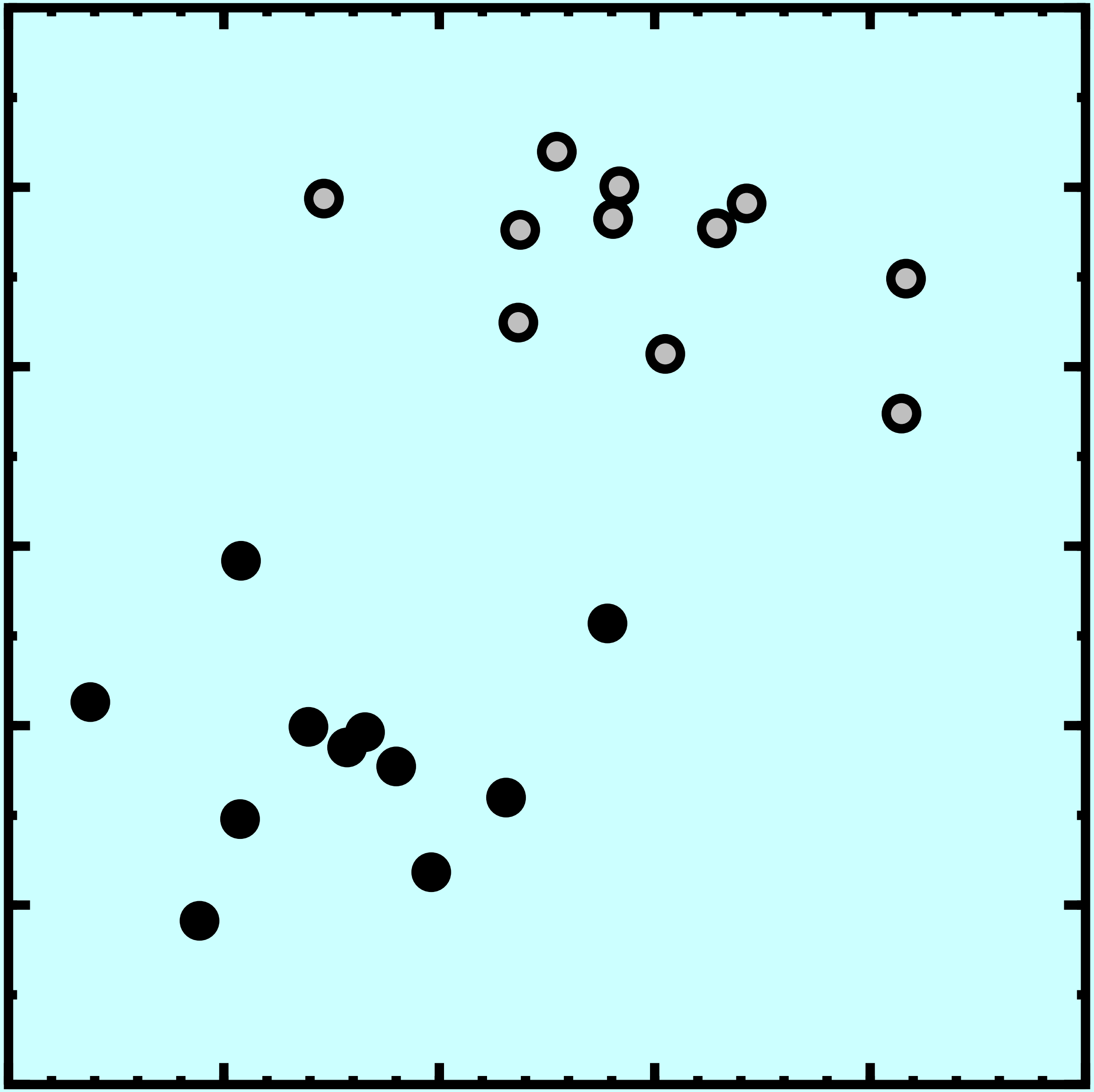
A simple case to show effects of phylogeny



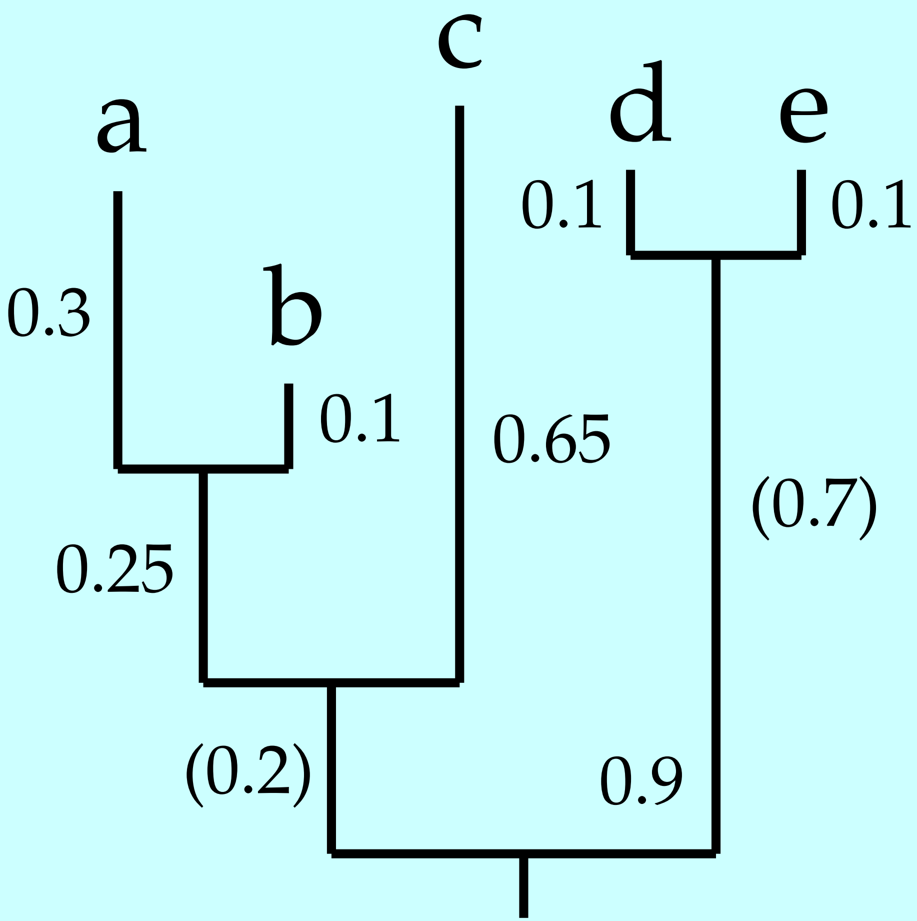
Two uncorrelated characters evolving on that tree



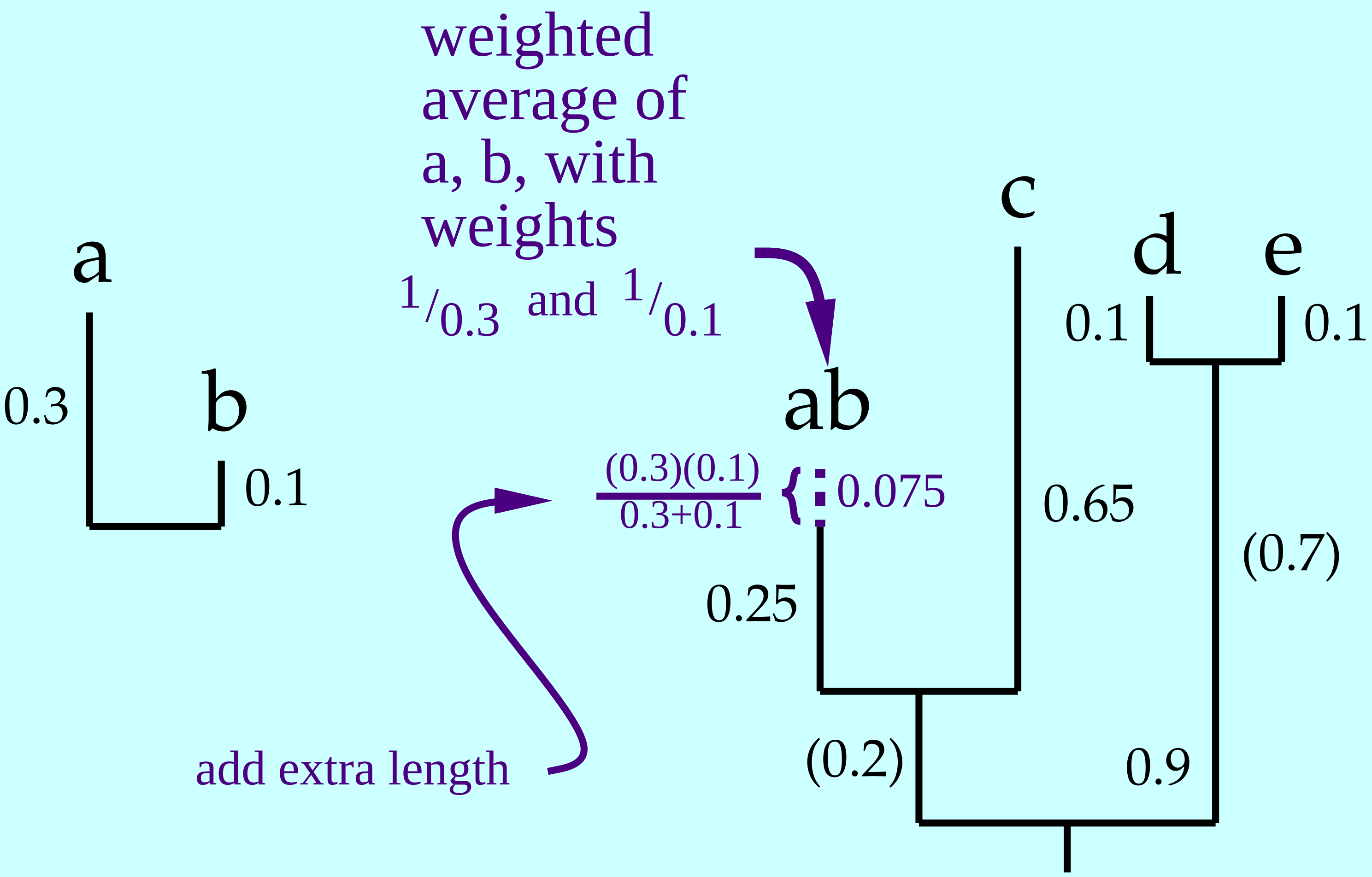
Identifying the two clades



A tree on which we are to observe two characters



This turns out to be statistically equivalent to ...



weighted average of a, b, with weights $^{1}/_{0.3}$ and $^{1}/_{0.1}$

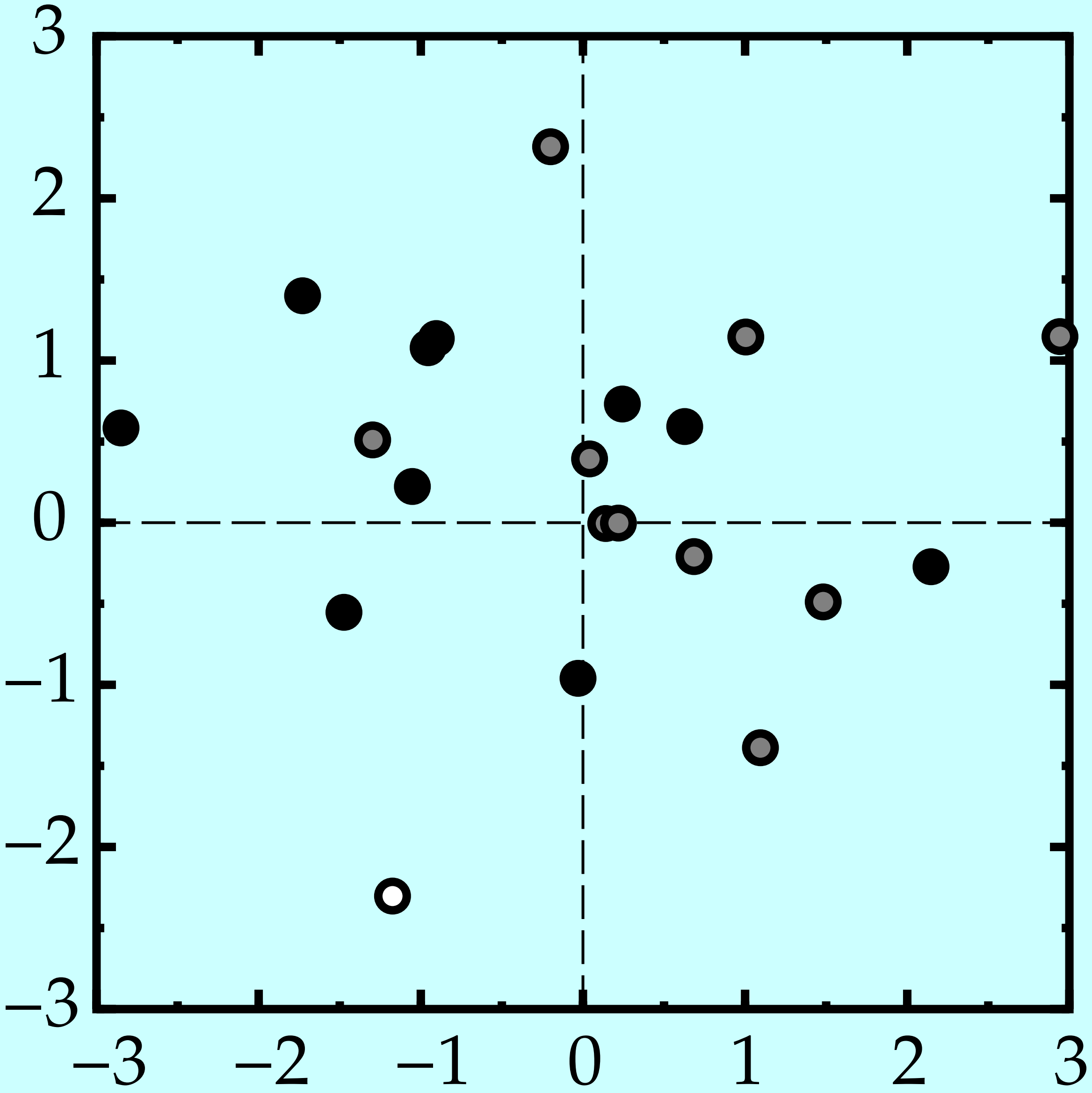
$\frac{(0.3)(0.1)}{0.3+0.1}$ { 0.075

add extra length

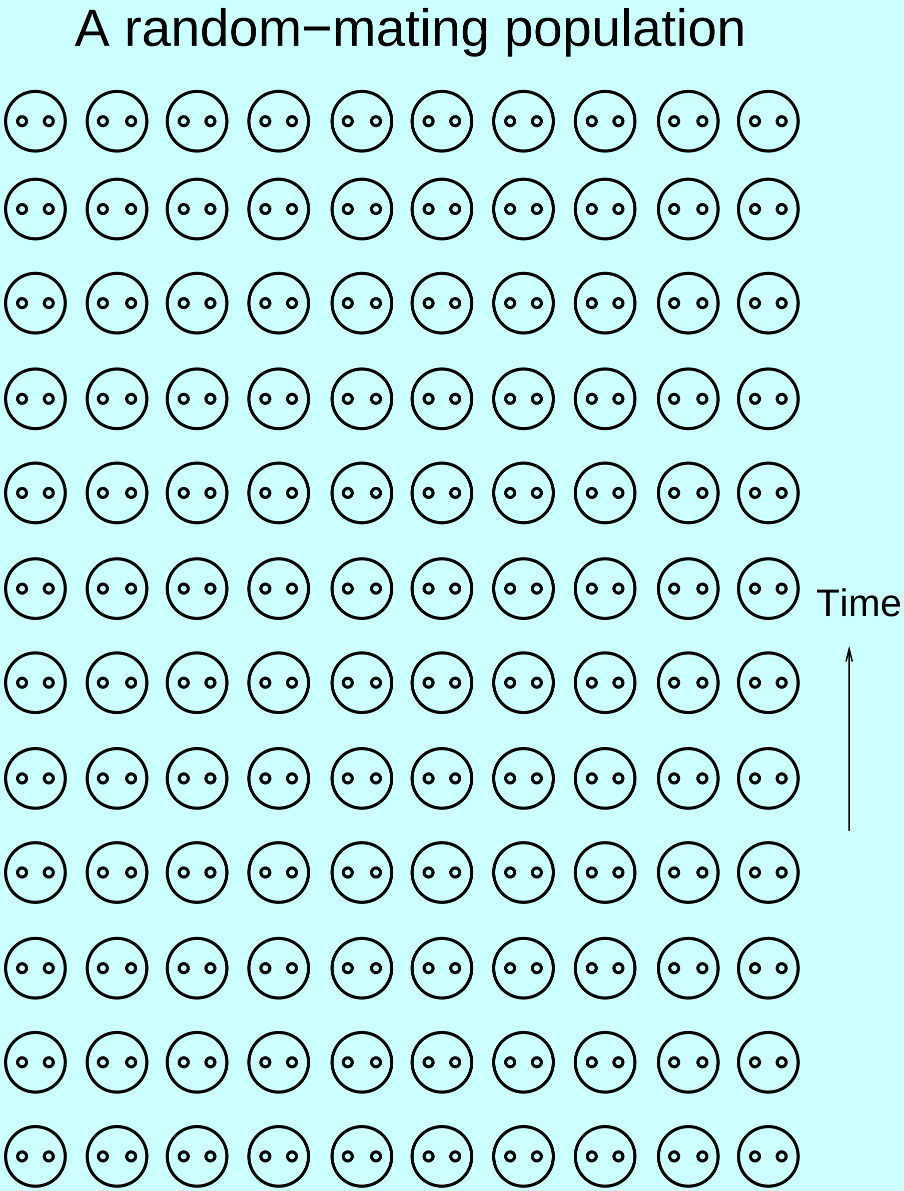
Contrasts on that tree

Contrast	Variance proportional to
$y_1 = x_a - x_b$	0.4
$y_2 = \frac{1}{4}\, x_a + \frac{3}{4}\, x_b - x_c$	0.975
$y_3 = x_d - x_e$	0.2
$y_4 = \frac{1}{6}\, x_a + \frac{1}{2}\, x_b + \frac{1}{3}\, x_c - \frac{1}{2}\, x_d - \frac{1}{2}\, x_e$	1.11666

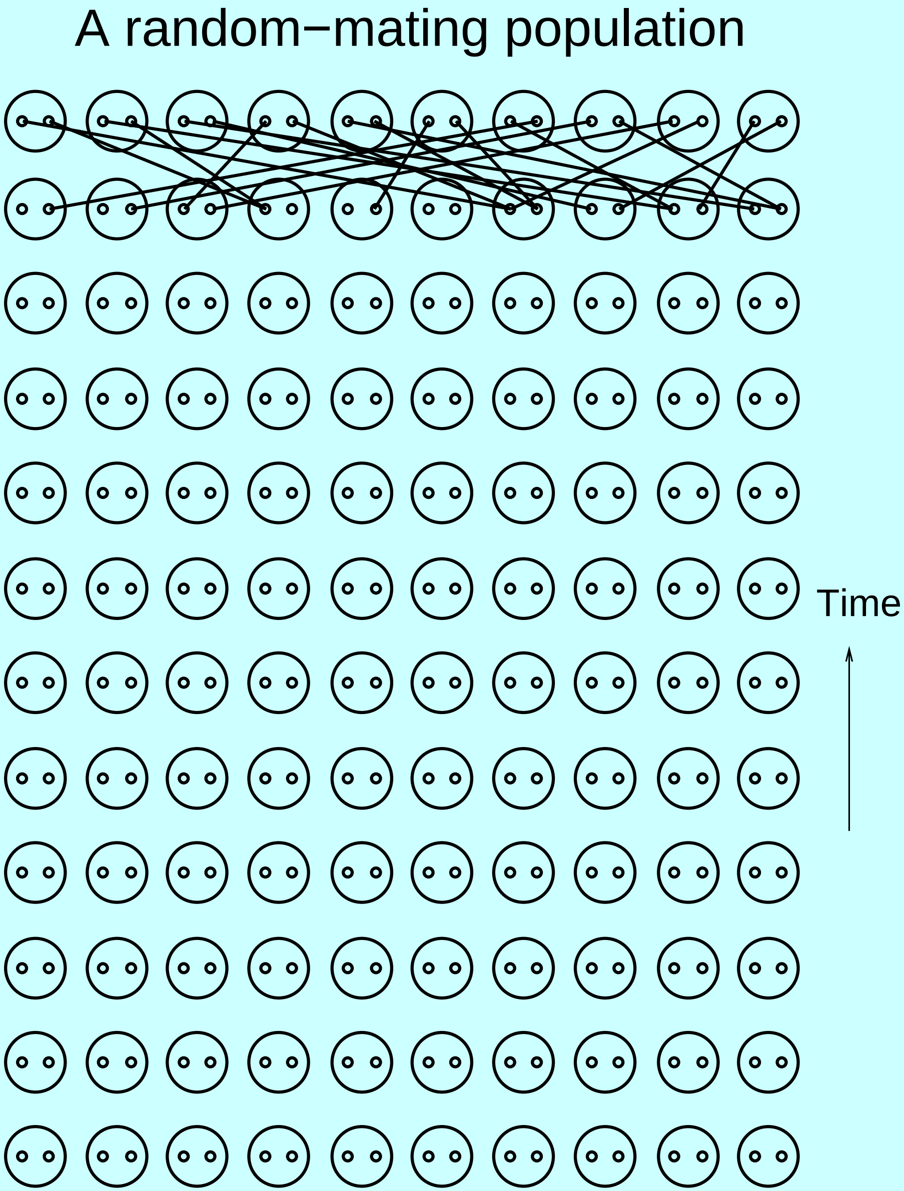
Plot standardized contrasts against each other



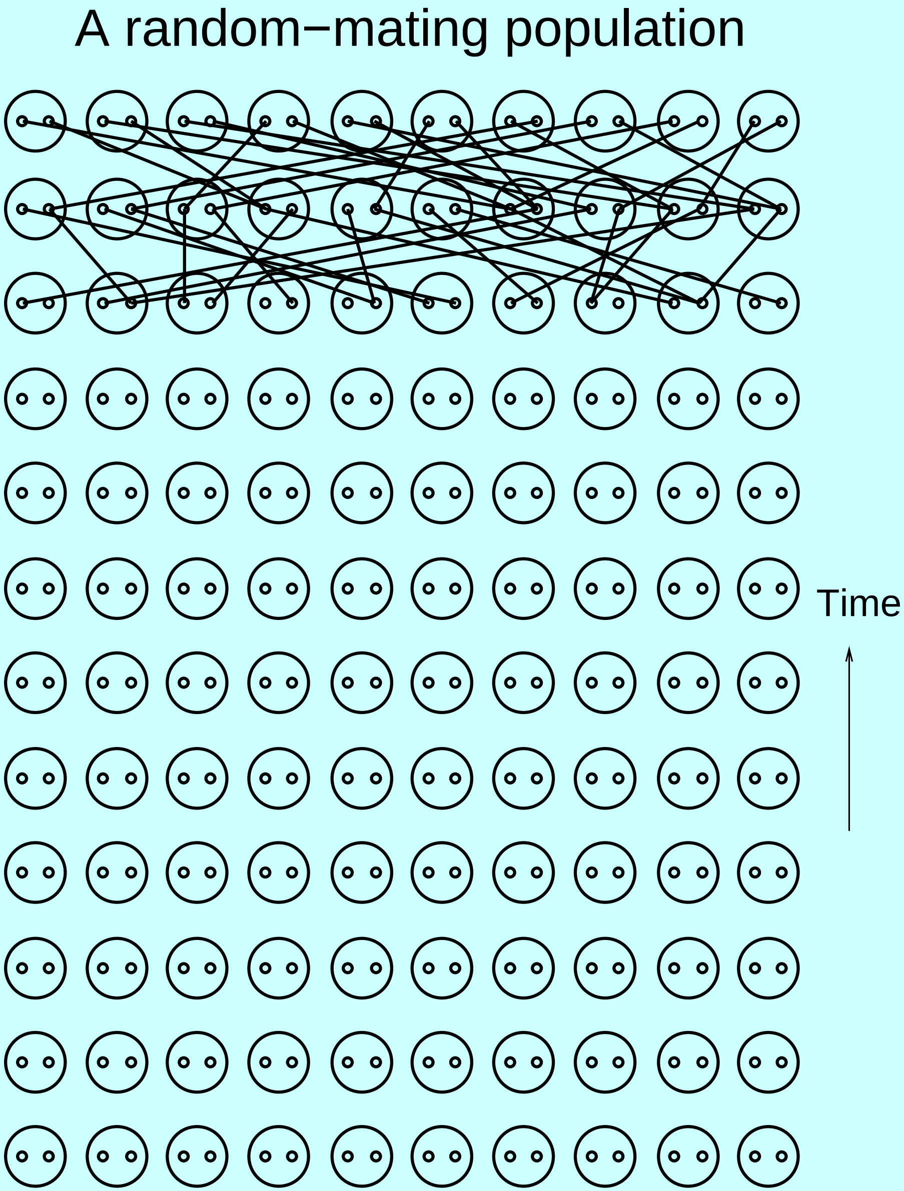
Gene copies in a population of 10 individuals



Going back one generation



... and one more



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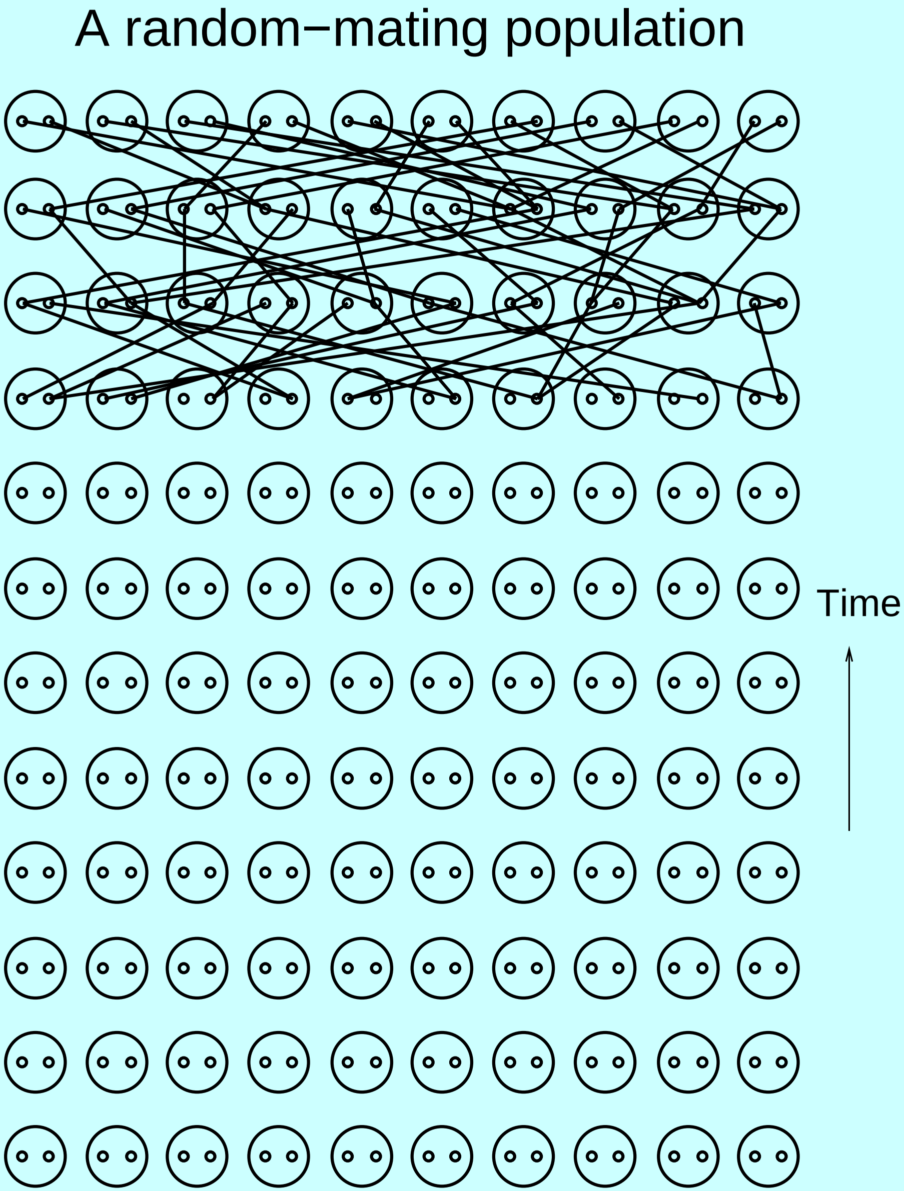

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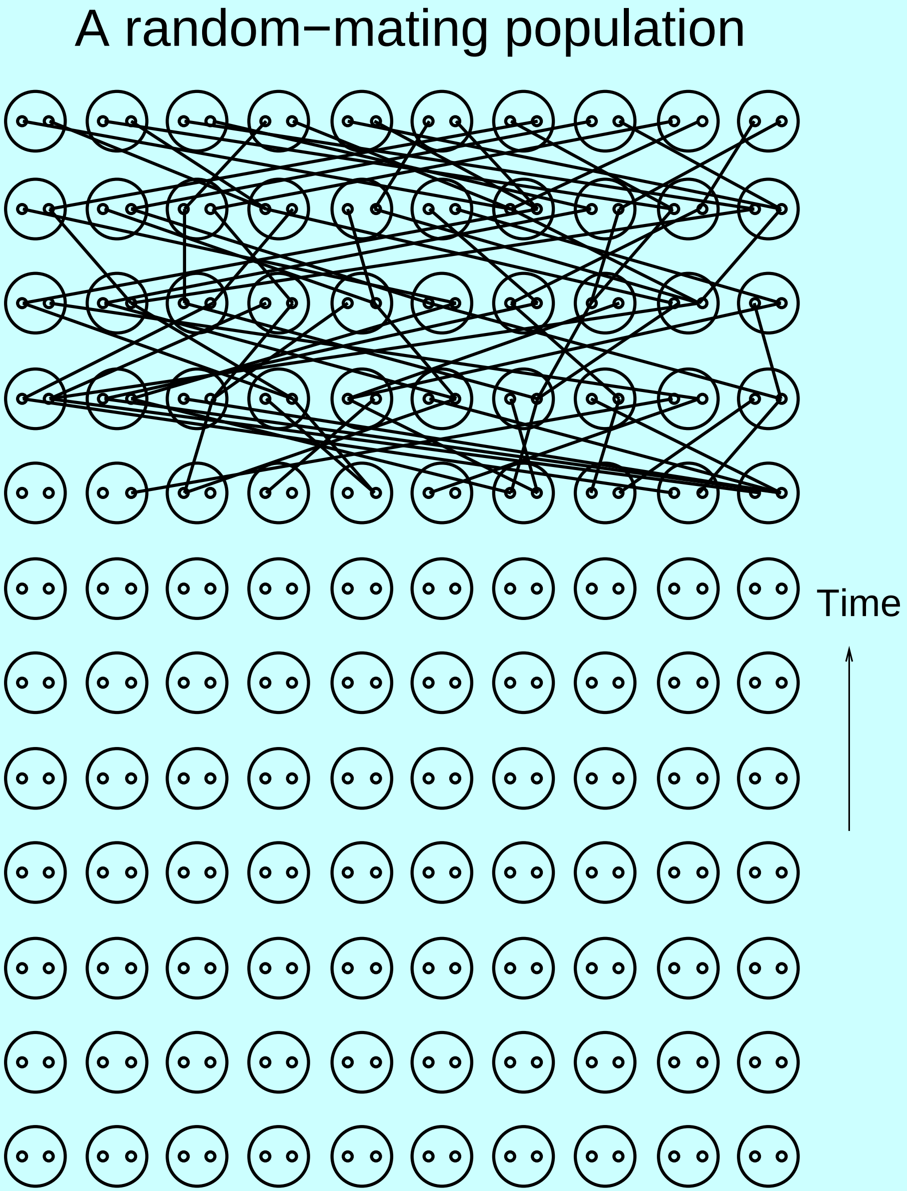

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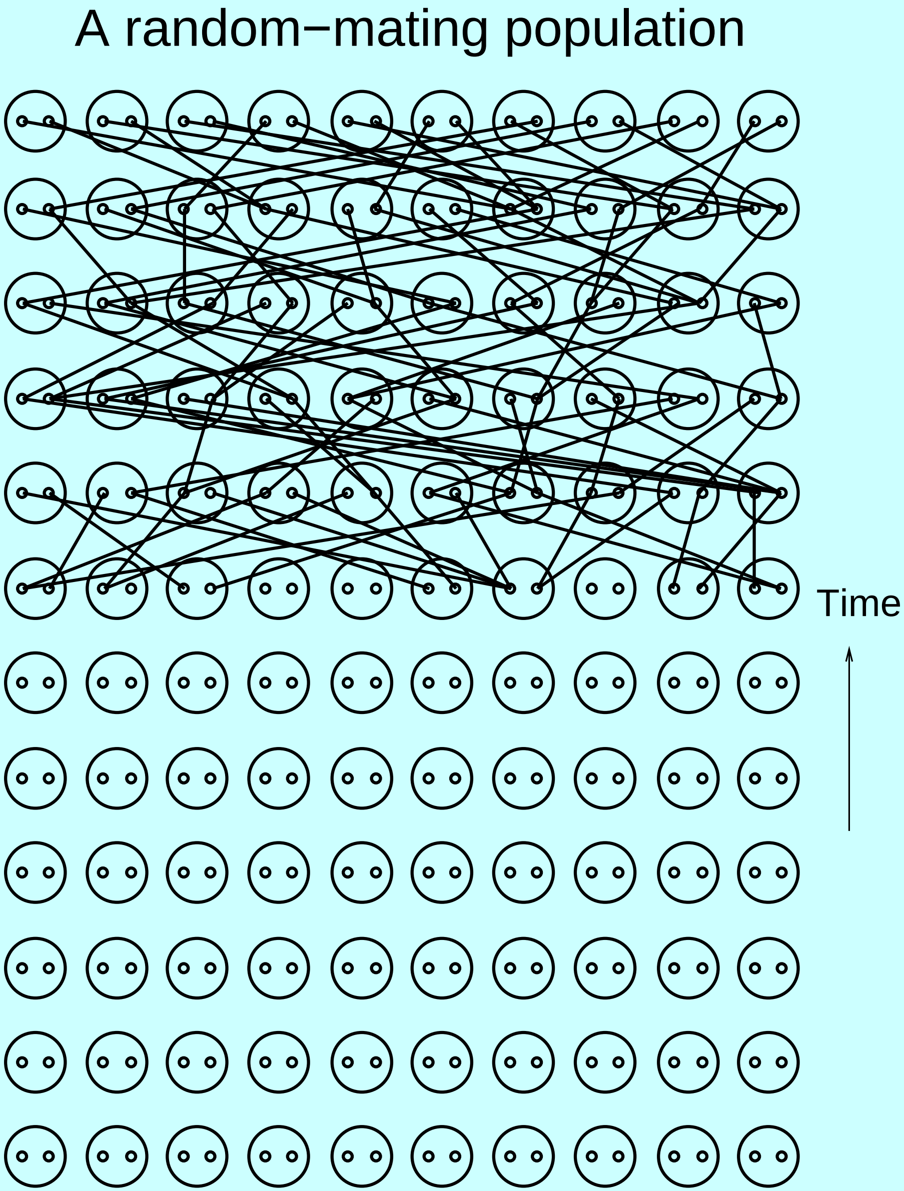

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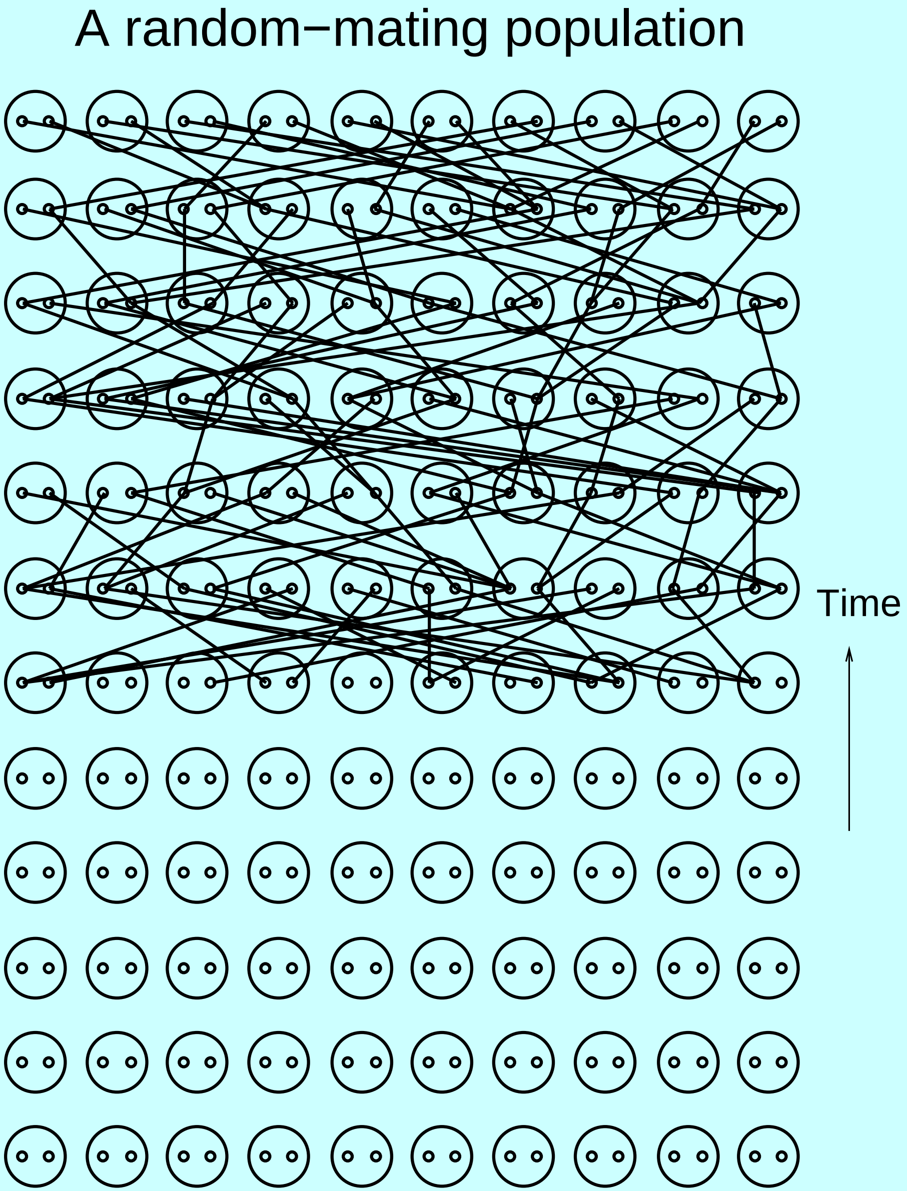

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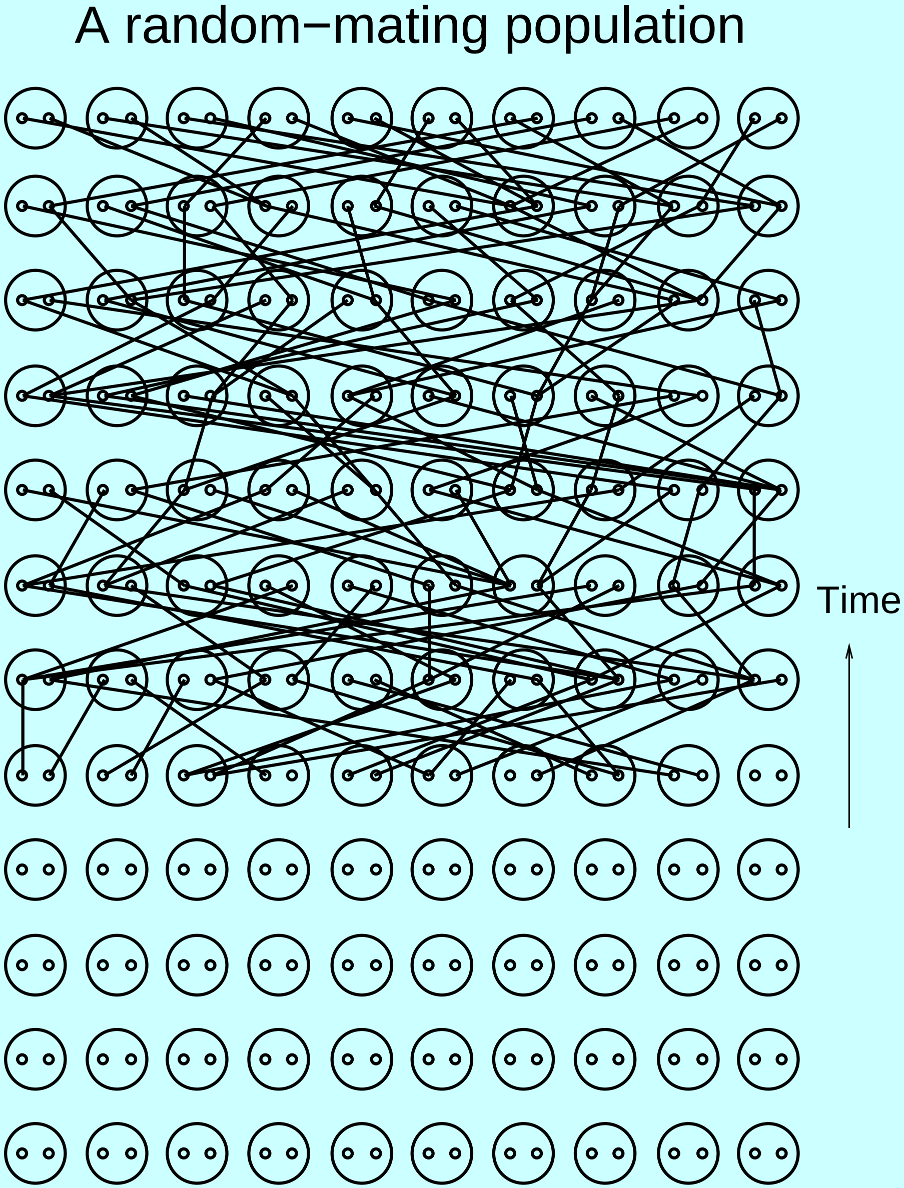

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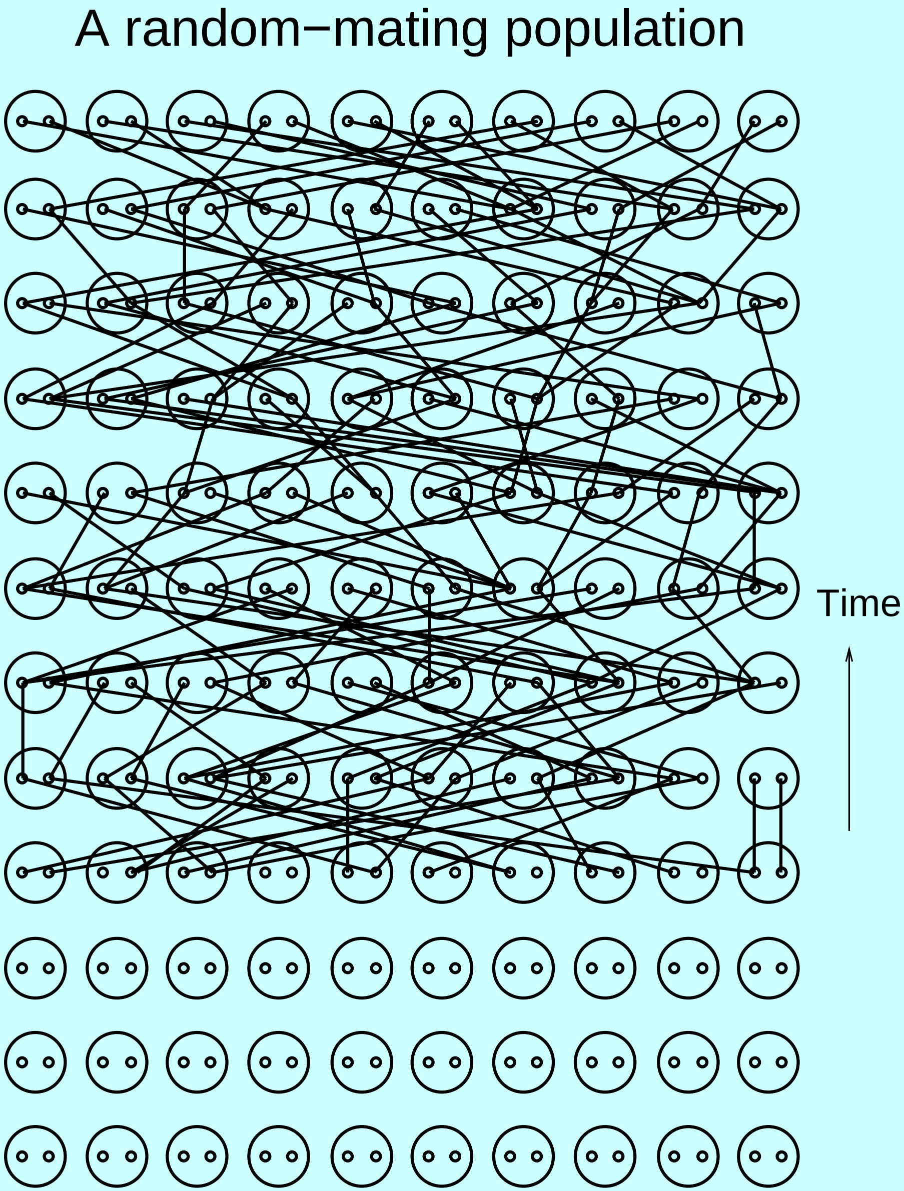

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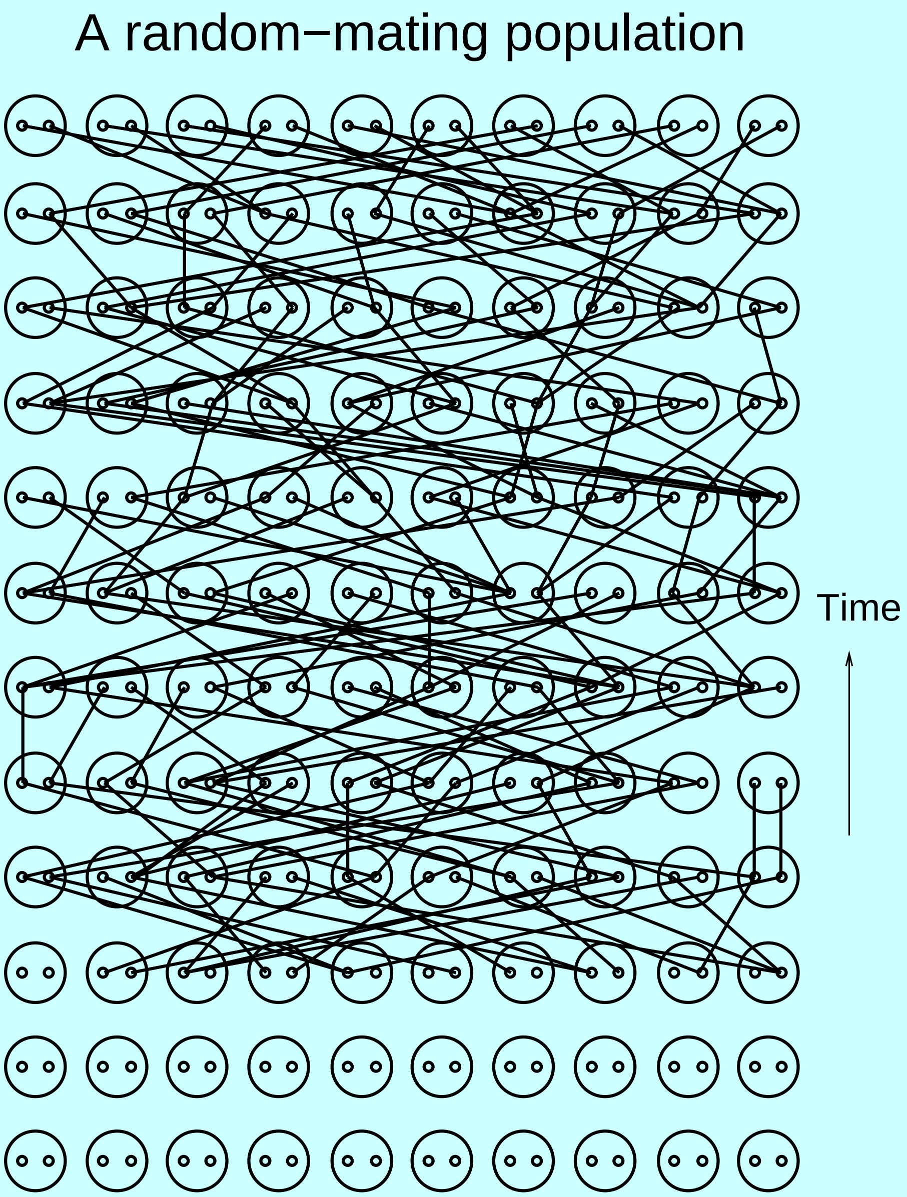

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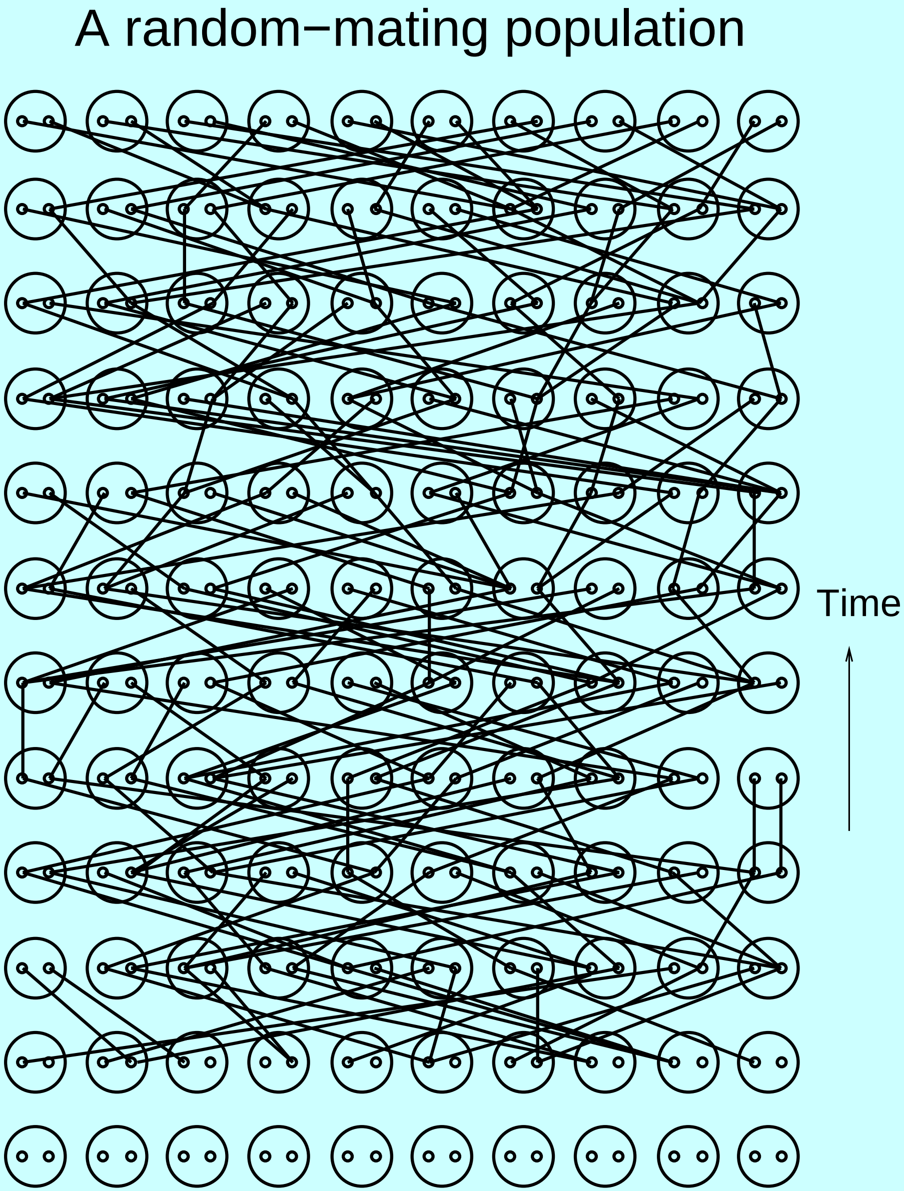
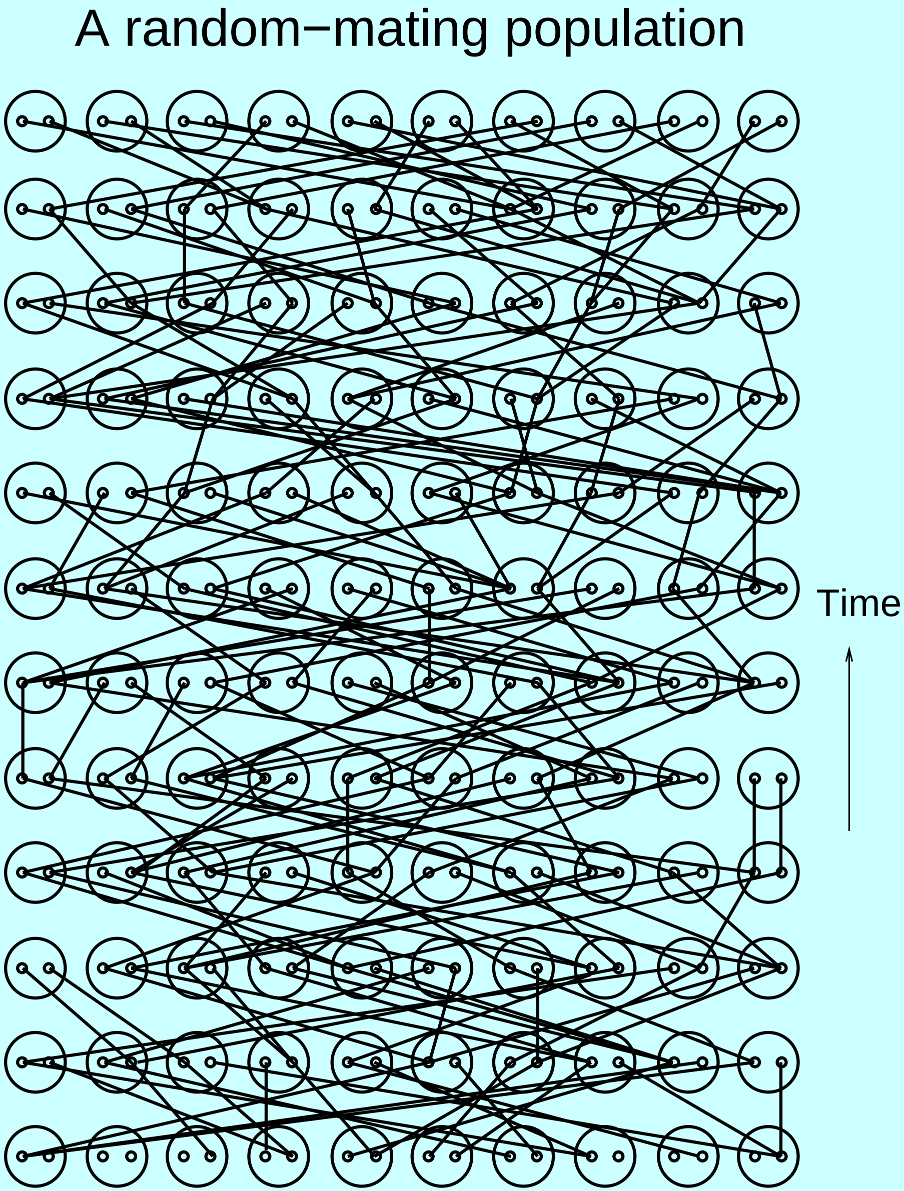
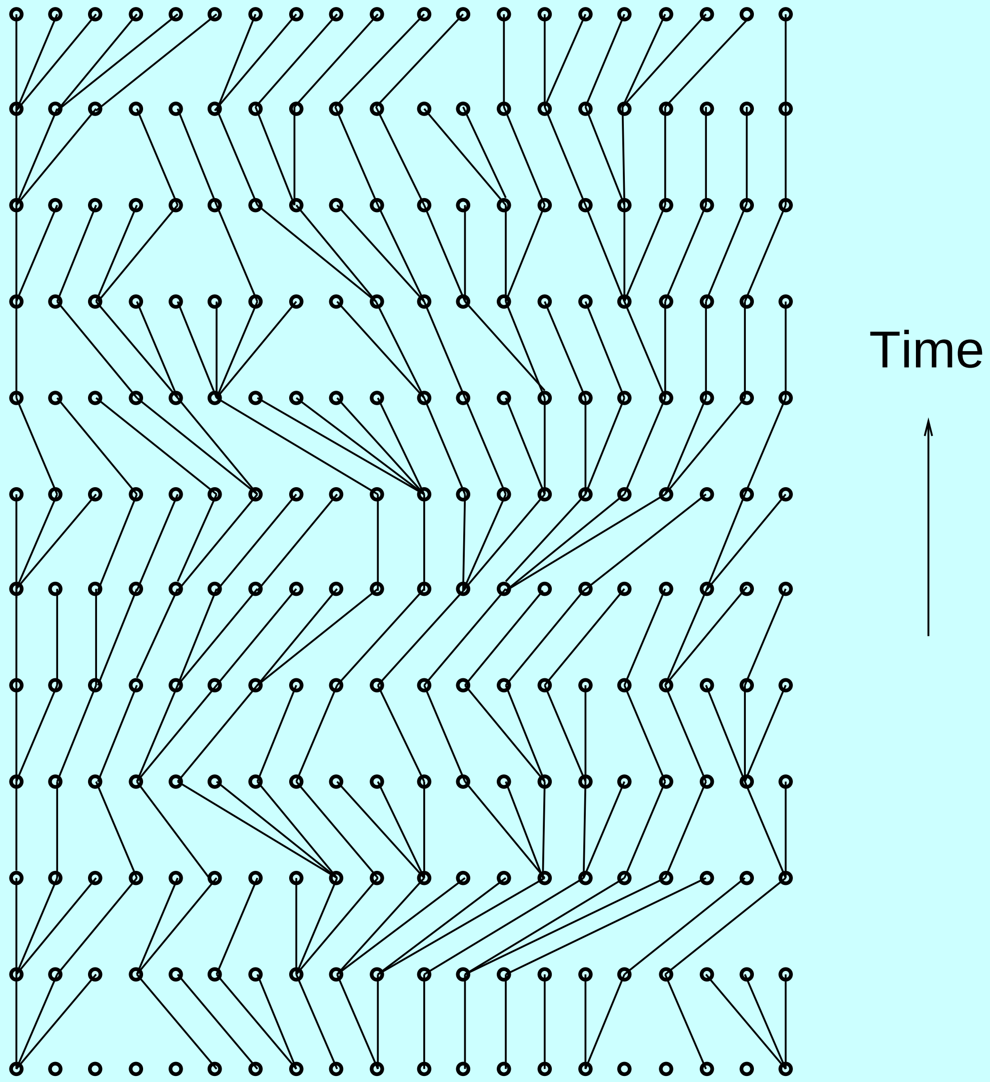


showing ancestry of gene copies



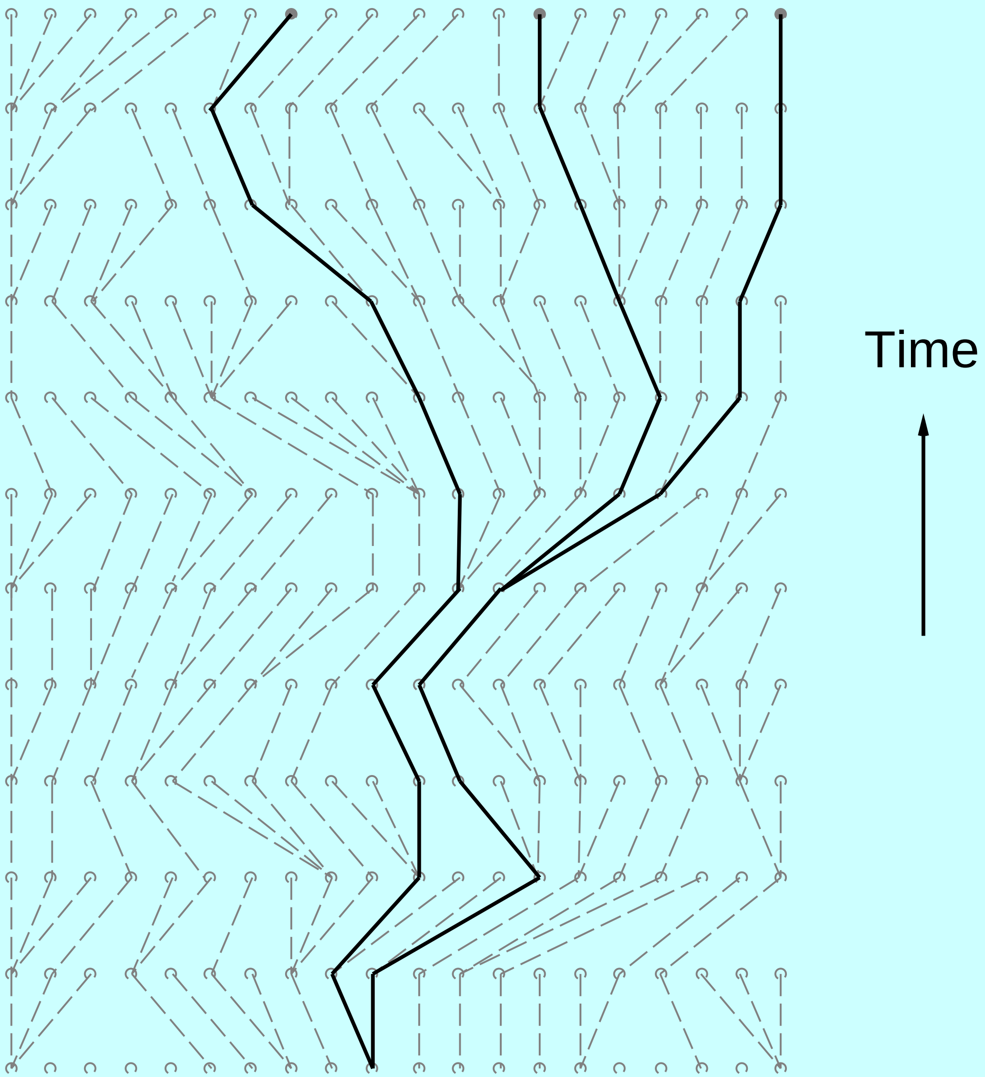
The genealogy of gene copies is a tree

Genealogy of gene copies, after reordering the copies

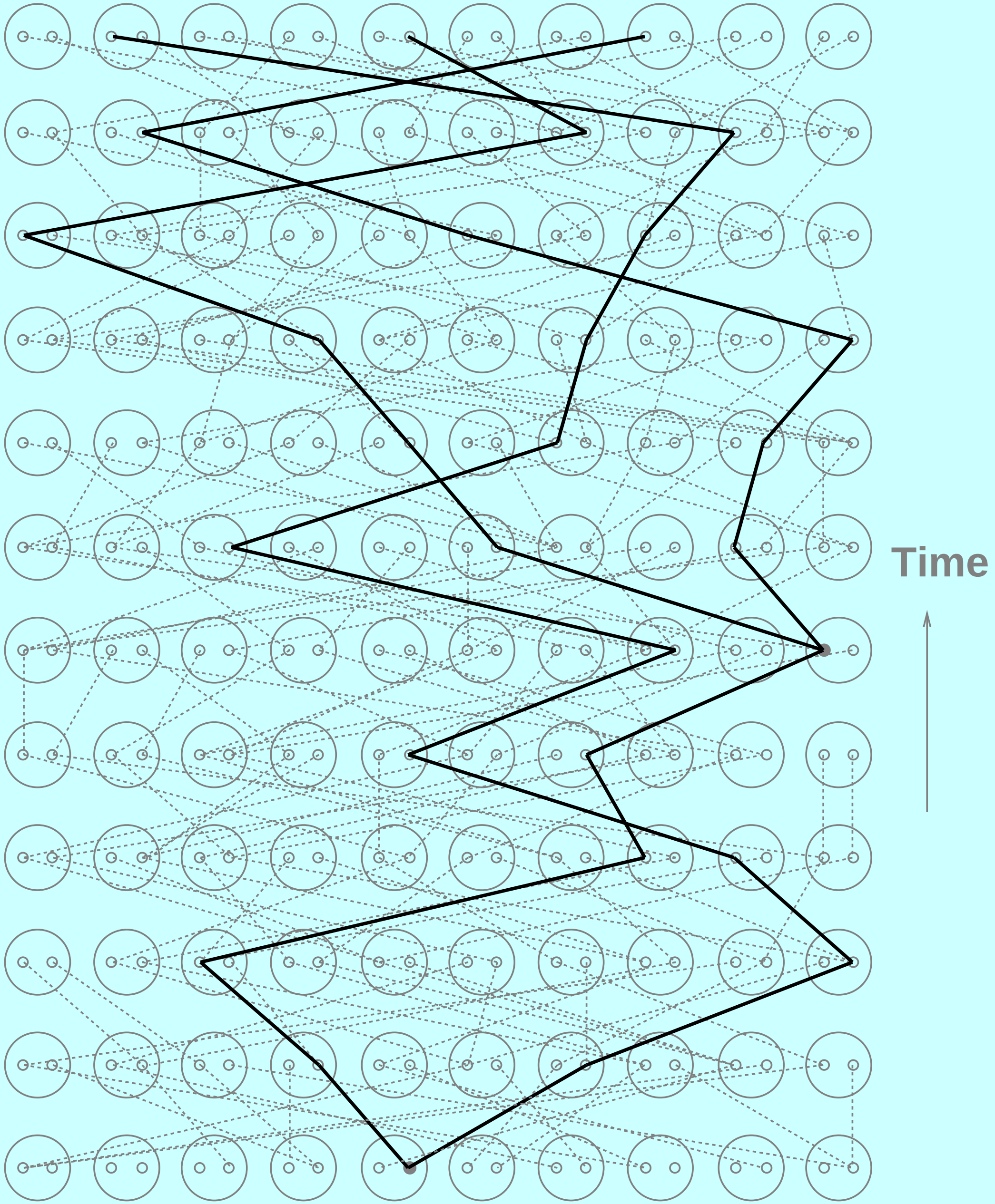


Ancestry of a sample of 3 copies

Genealogy of a small sample of genes from the population



Here is that tree of 3 copies in the pedigree



Kingman’s coalescent

Coalescent trees of gene copies within species (Kingman, 1982)

Random collision of lineages as go back in time (sans recombination)

Collision is faster the smaller the effective population size

Average time for

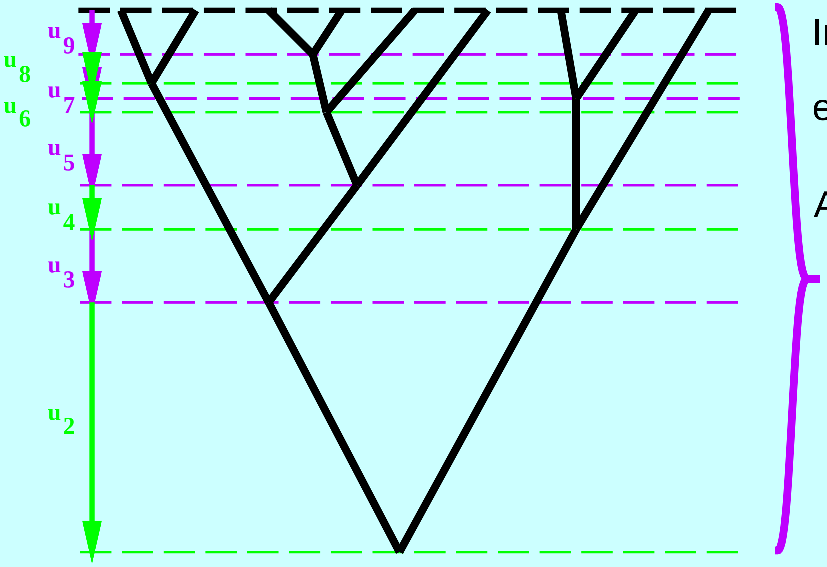
k copies to coalesce to

$$k-1 \quad = \quad \frac{4N}{k(k-1)}$$

Average time for

two copies to coalesce

= 2N generations



In a diploid population of

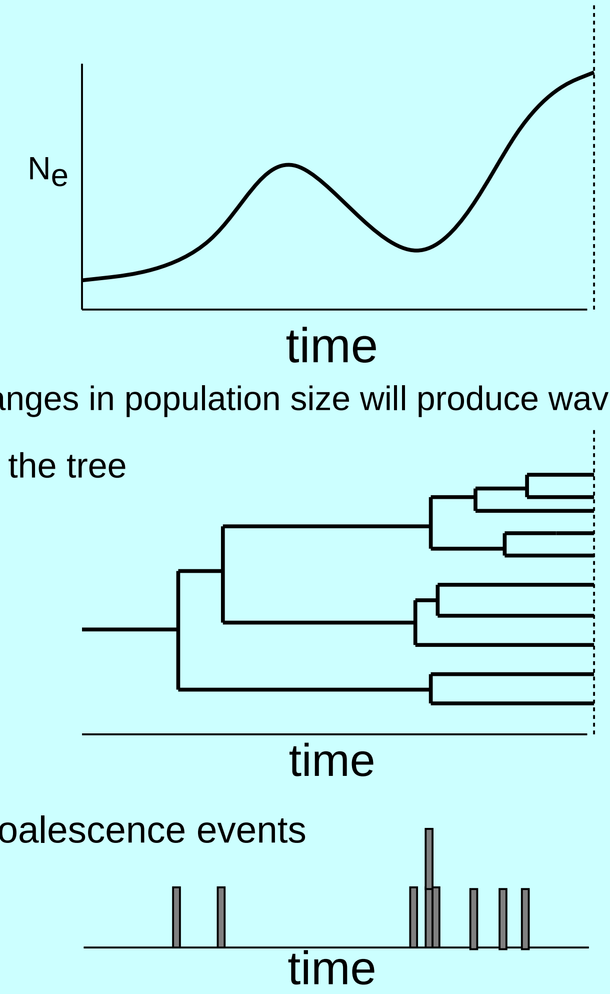
effective population size N,

Average time for n copies to coalesce

$$= \quad 4N\left(1 - \frac{1}{n}\right) \text{ generations}$$

Coalescence is faster in small populations

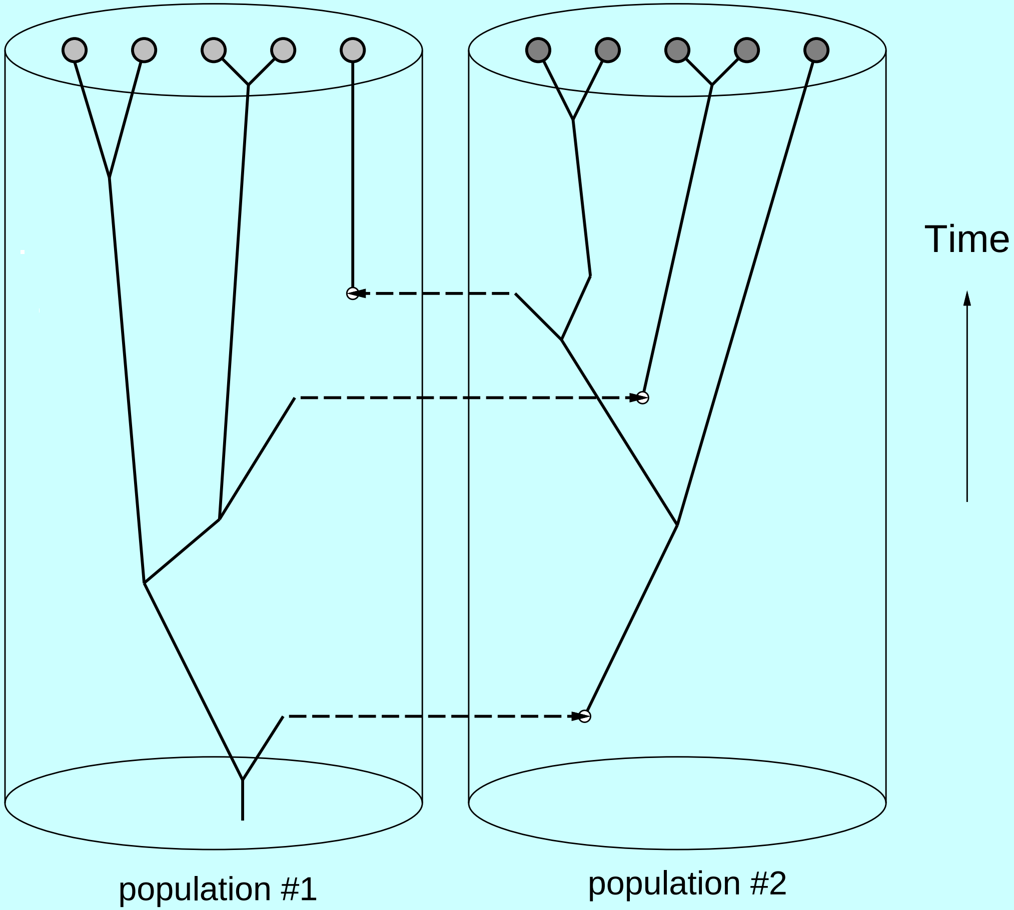
Change of population size and coalescents



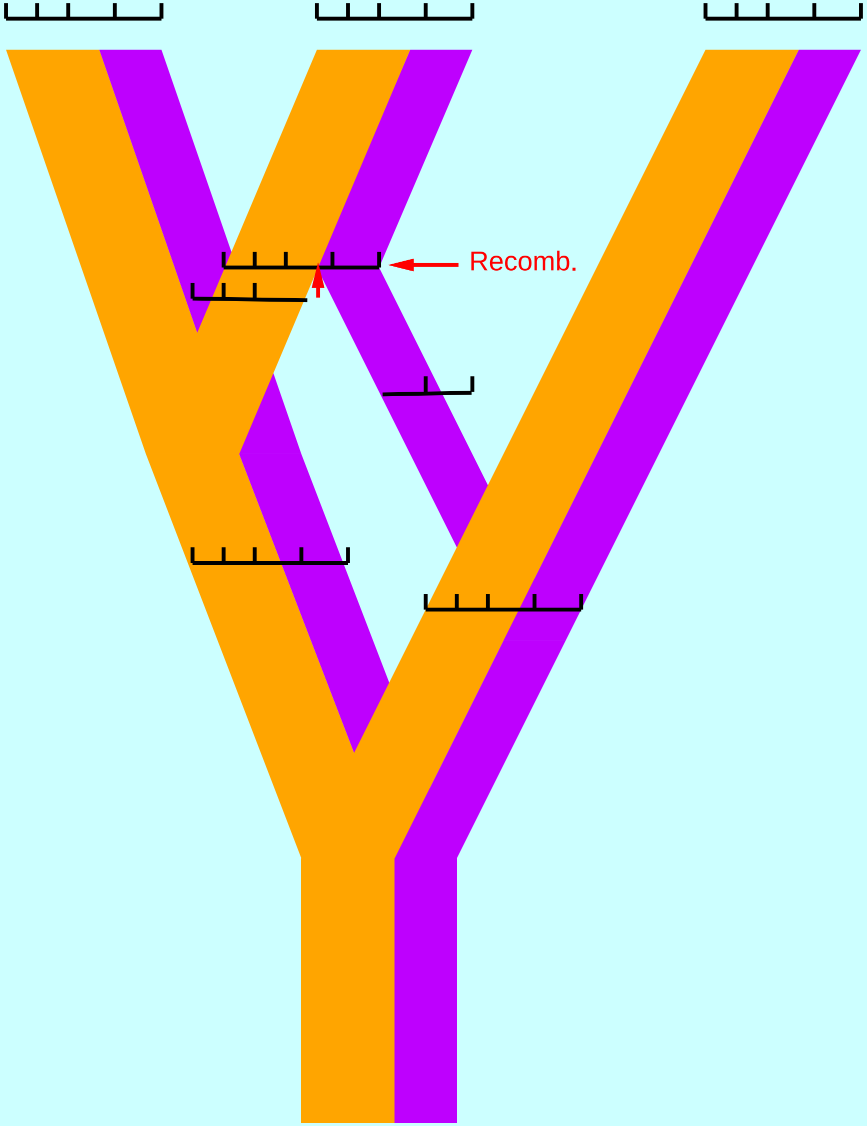
the changes in population size will produce waves of coalescence

The parameters of the growth curve for N_e can be inferred by likelihood methods as they affect the prior probabilities of those trees that fit the data.

Migration can be taken into account

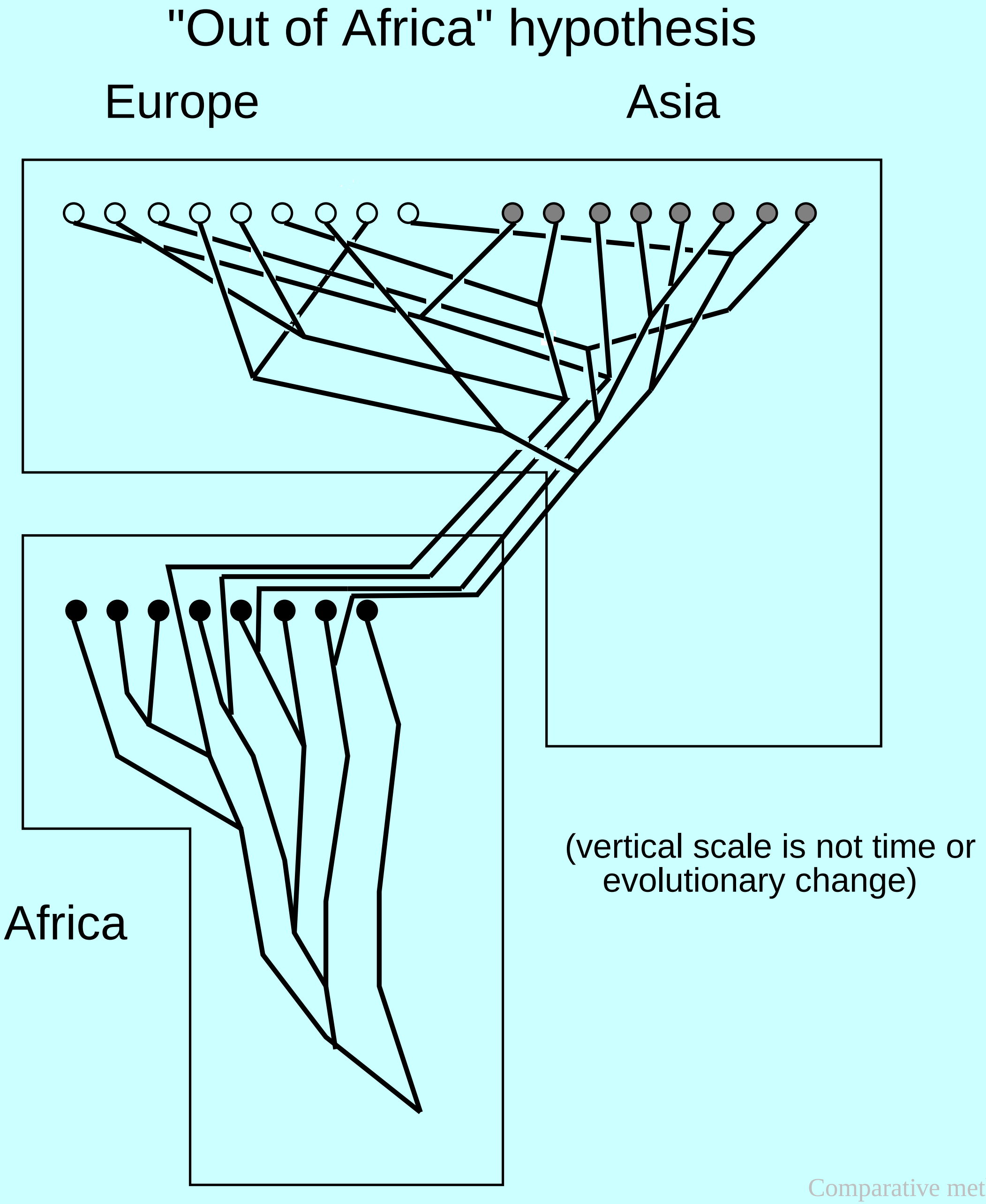


Recombination creates loops



Different markers have slightly different coalescent trees

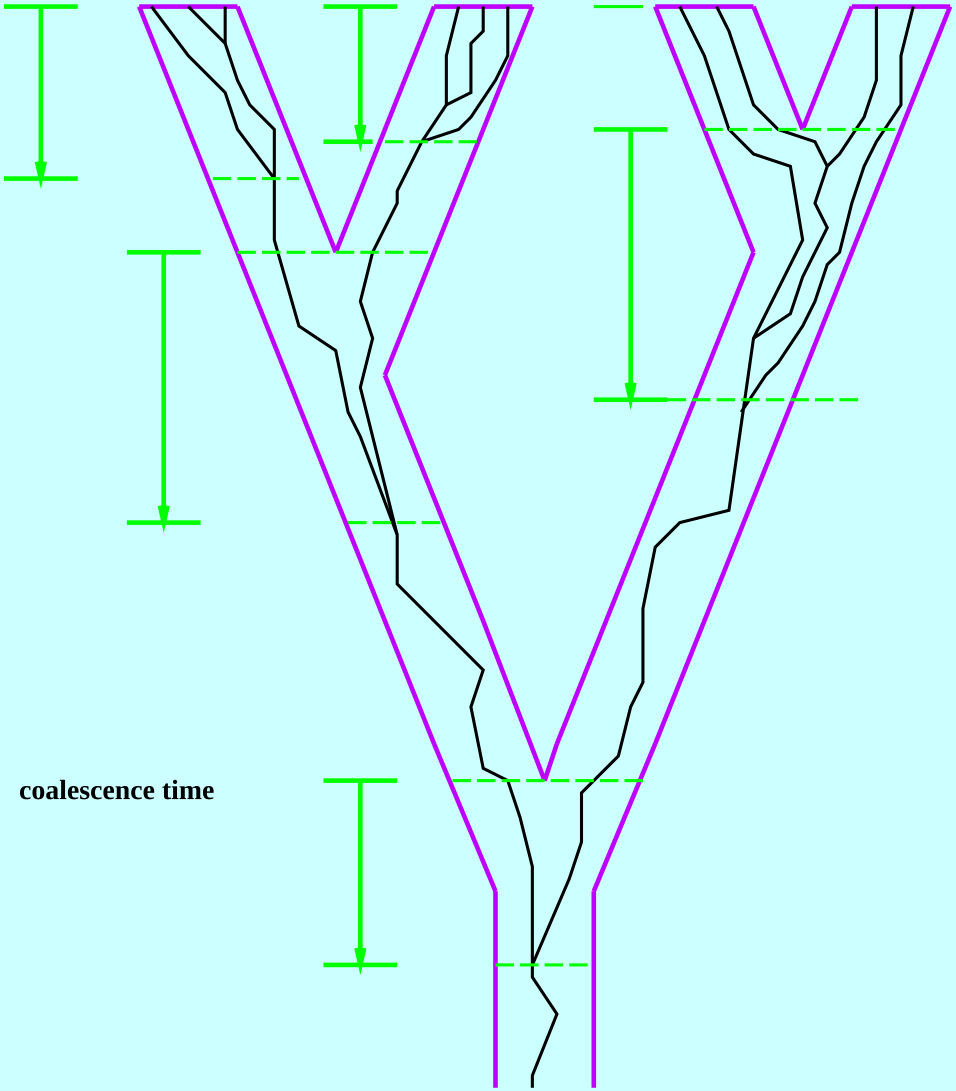
We want to be able to analyze human evolution



(vertical scale is not time or evolutionary change)

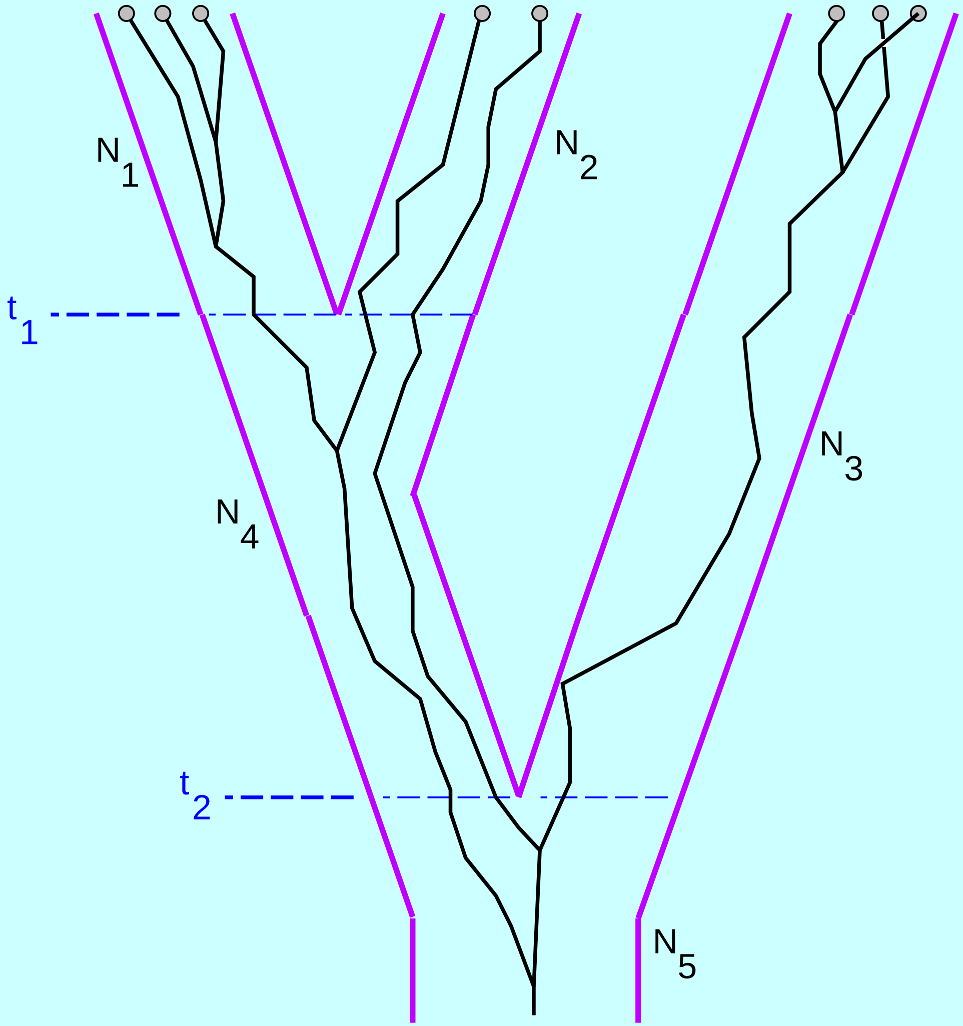
coalescent and “gene trees” versus species trees

Consistency of gene tree with species tree



If the branch is more than N_e generations long ...

Gene tree and Species tree



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- ... and more approximately by Approximate Bayesian Computation (ABC) methods. Faster but not necessarily as efficient statistically.

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- Integration of between-species and between-population studies with morphological characters.

References

Comparative methods

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Harvey, P. H. and M. D. Pagel. 1991. *The Comparative Method in Evolutionary Biology.* Oxford University Press, Oxford. [Reviews early work by me, Mark Ridley and the authors on comparative methods]

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The coalescent

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(continued)

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Nielsen, R. and M. Slatkin. 2013. An Introduction to Population Genetics. Theory and Applications. Sinauer Associates, Sunderland, Massachusetts. Population genetics textbook with more coverage of coalescents than usual.

Felsenstein, J. 2004. *Inferring Phylogenies.* Sinauer Associates, Sunderland, Massachusetts. [Especially chapter 27 which covers MCMC likelihood approaches (but explanation of logic of Griffiths/Tavaré method is wrong)]

Felsenstein, J. 2007. Trees of genes in populations. pp. 3-29 in *Reconstructing Evolution. New Mathematical and Computational Advances*, pp. 3-27 in by O. Gascuel and M. Steel. Oxford University Press, Oxford. [Review of coalescents including MCMC, for a somewhat mathematical audience]