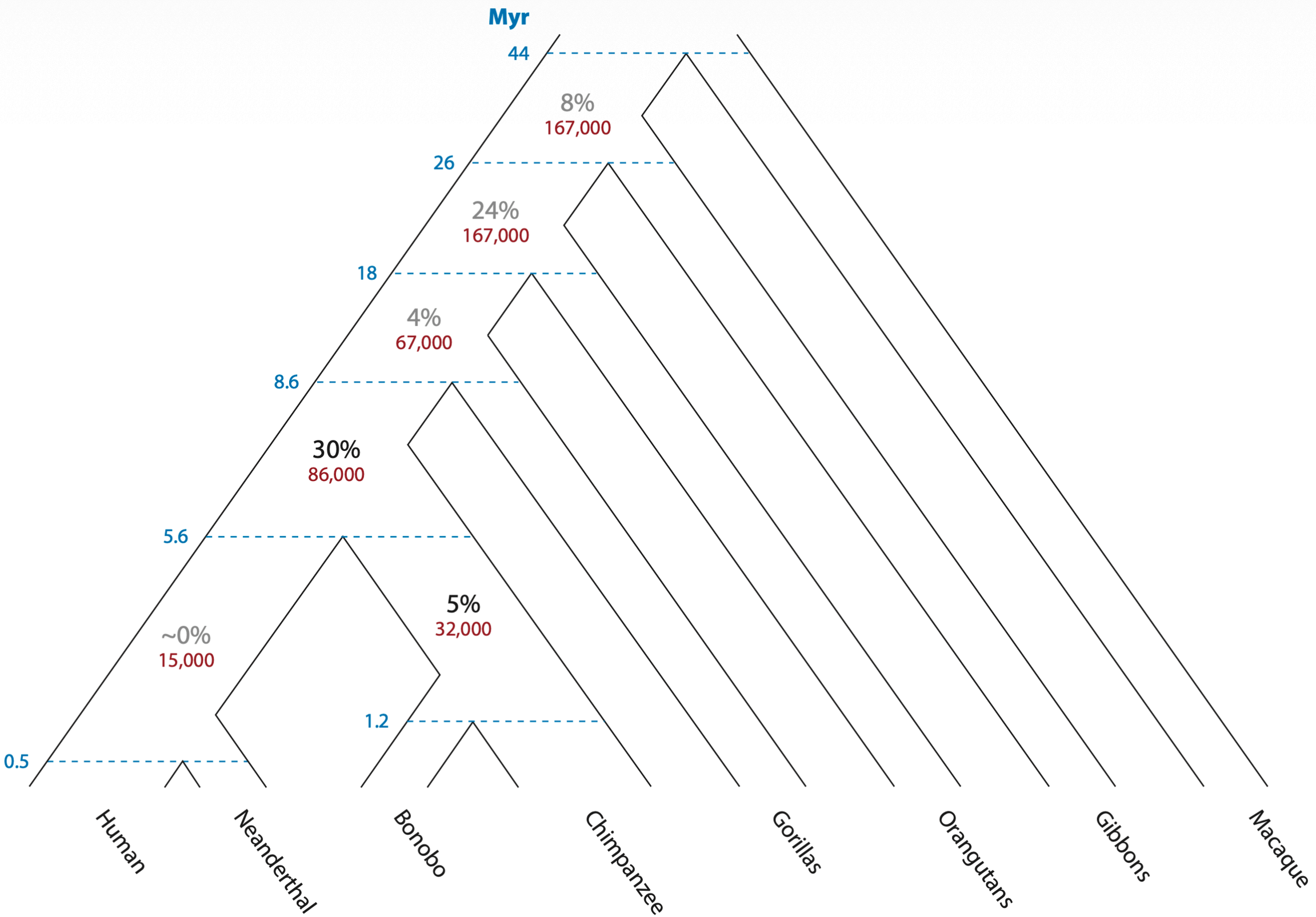
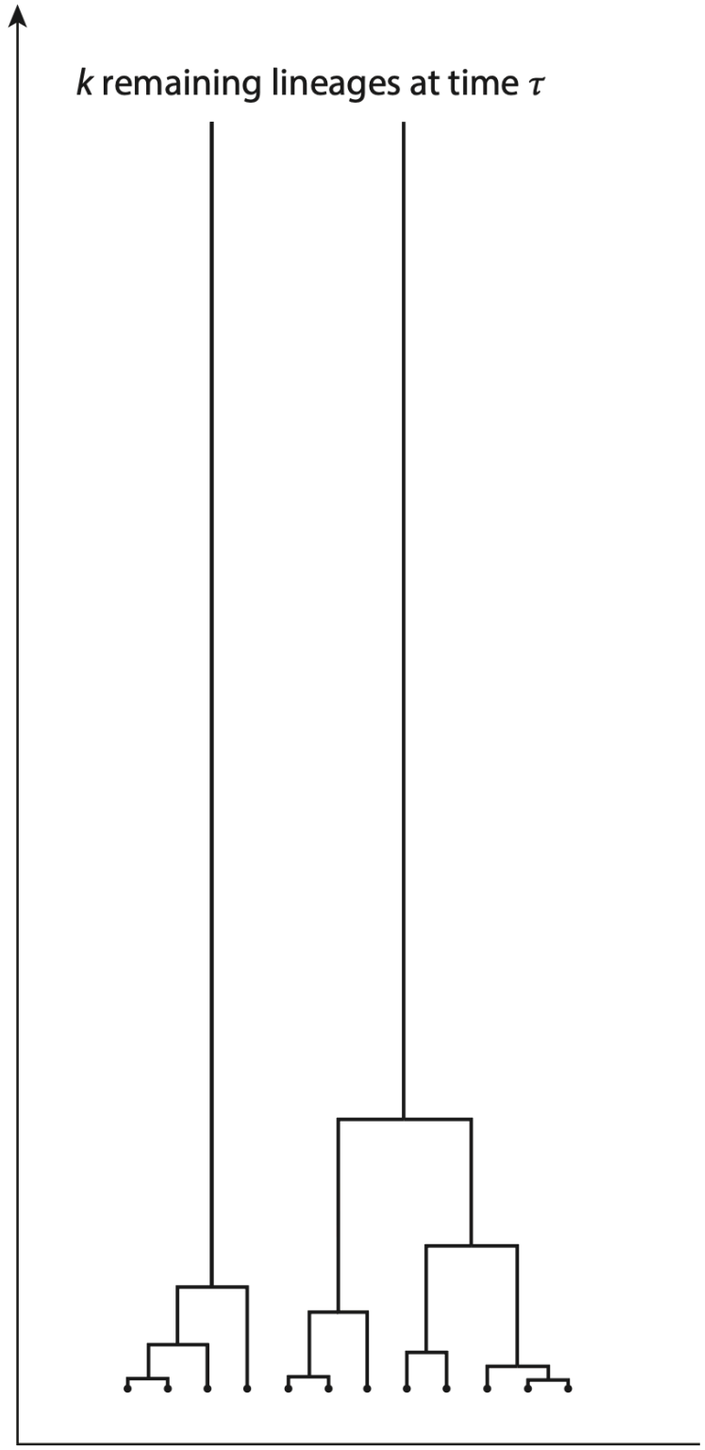
ILS Week

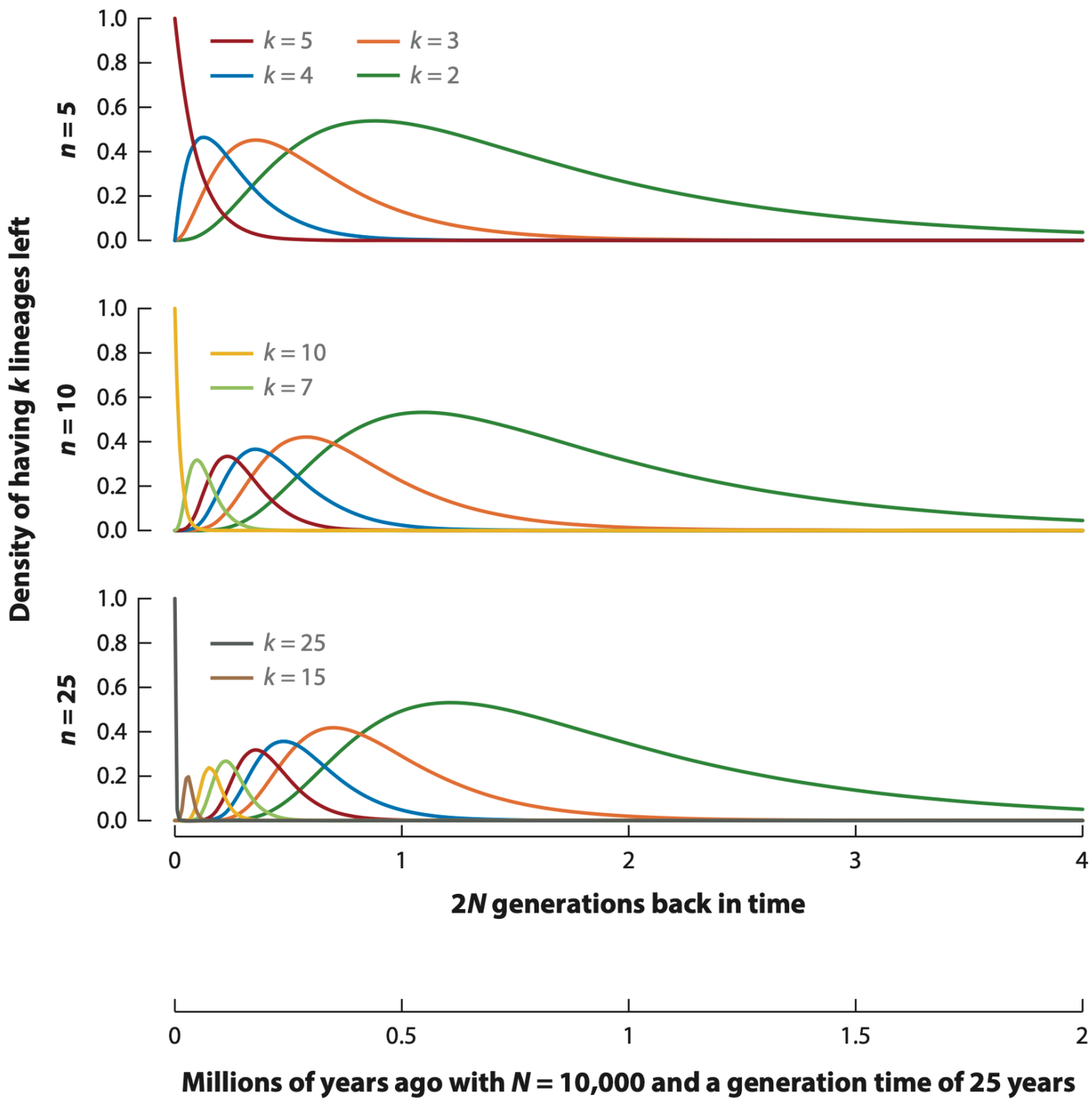
Kasper Munch

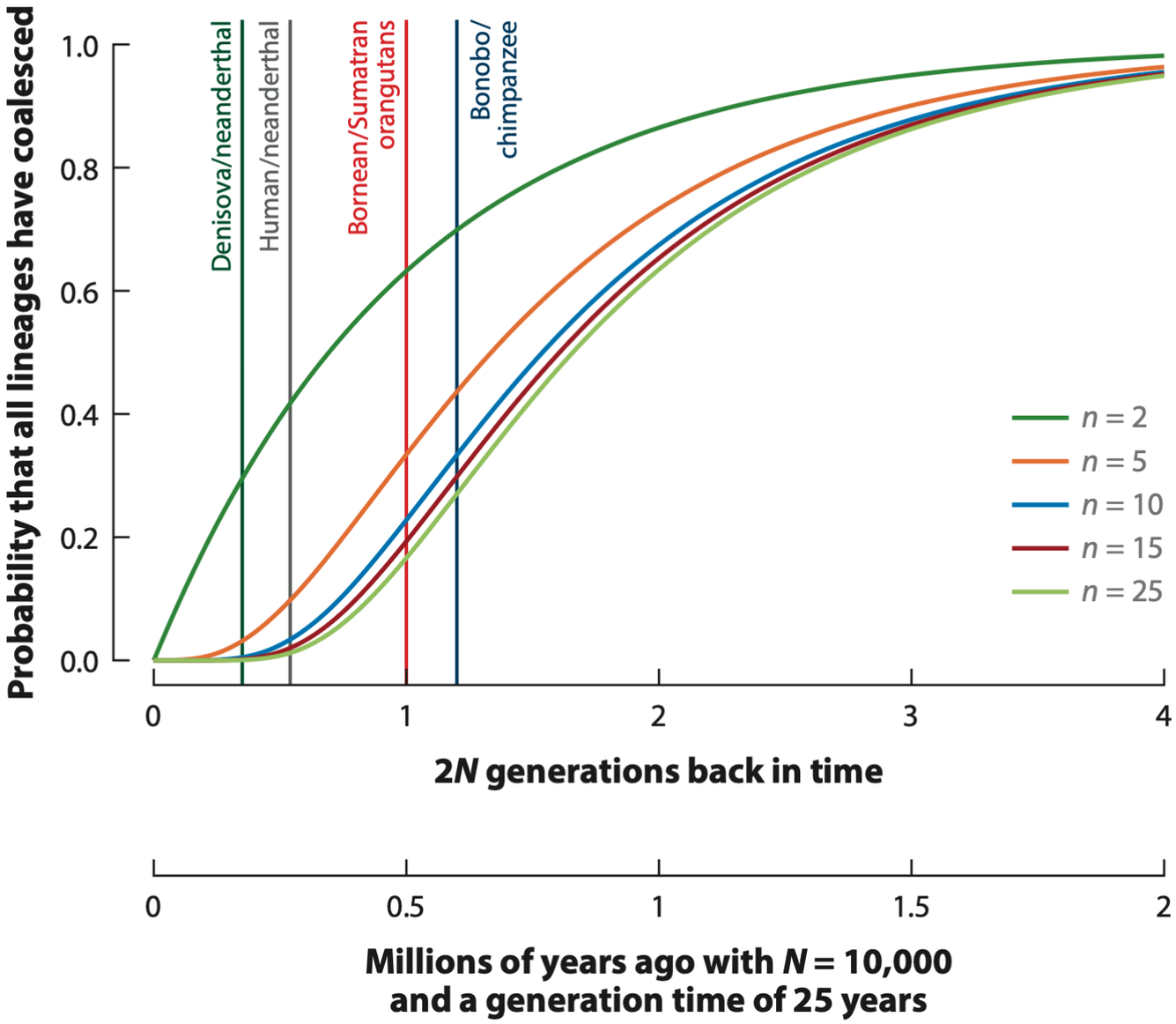
Table 1 The difference between speciation time (population divergence time) and average genomic divergence time for pairs of great ape species[a]

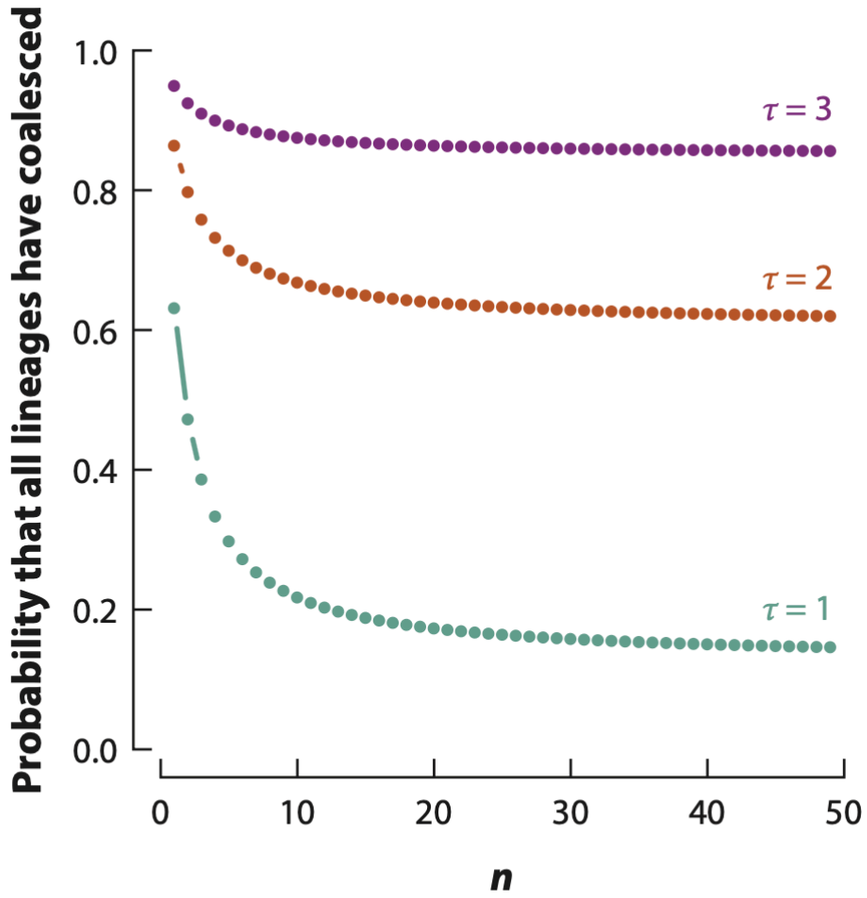
Species 1	Species 2	Generation time	Ancestral population size	Speciation time	Divergence time	Reference
Human	Neanderthal	29	15,000	0.55	1.42	(49)
Human	Chimpanzee	25	86,000	5.6	9.9	(46) ILS model
Human	Gorilla	25	67,000	8.6	12.0	(46) ILS model
Human	Orangutan	25	167,000	18.5	26.9	(46) CTMC model
Human	Macaque	25	196,667	44.0	53.8	(8)
Chimpanzee	Bonobo	25	32,000	1.2	2.8	(46) ILS model
Bornean orangutan	Sumatran orangutan	23	63,000	1	3.9	(46) CTMC model
West gorilla	East gorilla	20	64,000	0.4	2.9	(46) CTMC model

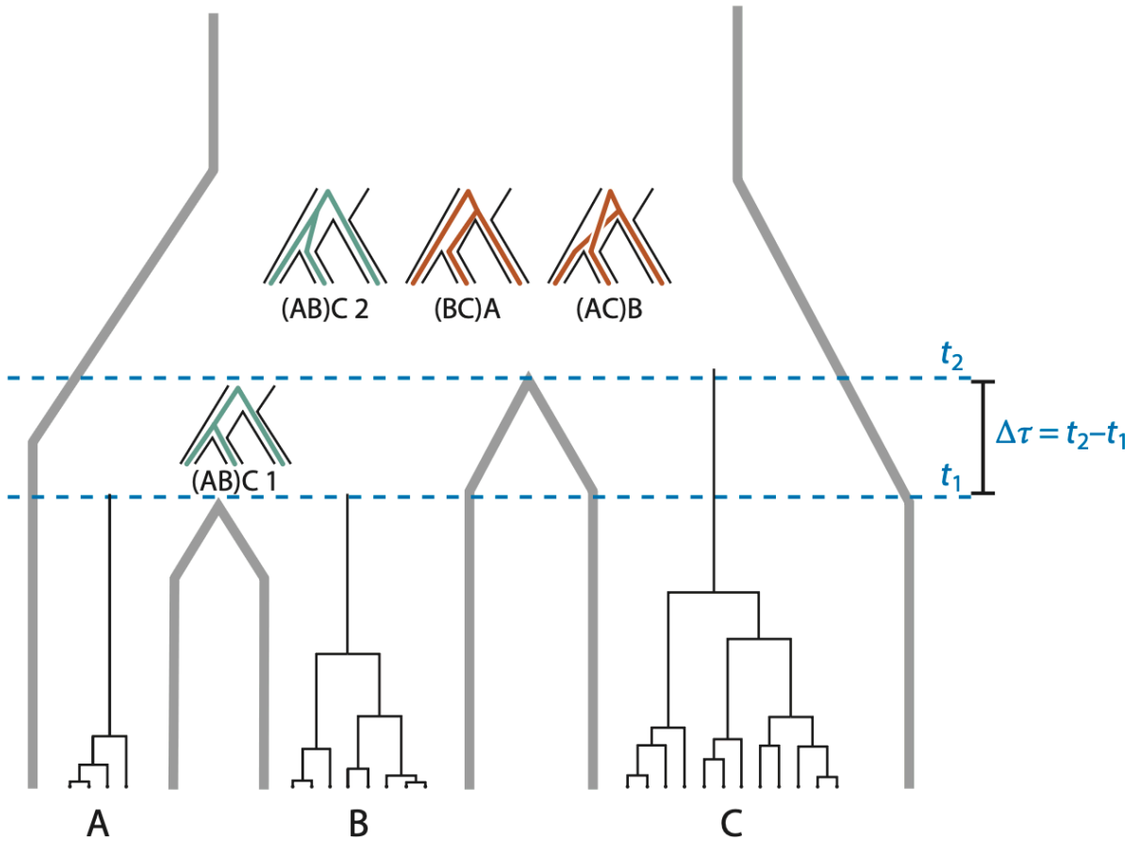

Myr
44
26
18
8.6
5.6
1.2
0.5
8%
167,000
24%
167,000
4%
67,000
30%
86,000
5%
32,000
~0%
15,000
Human
Neanderthal
Bonobo
Chimpanzee
Gorillas
Orangutans
Gibbons
Macaque

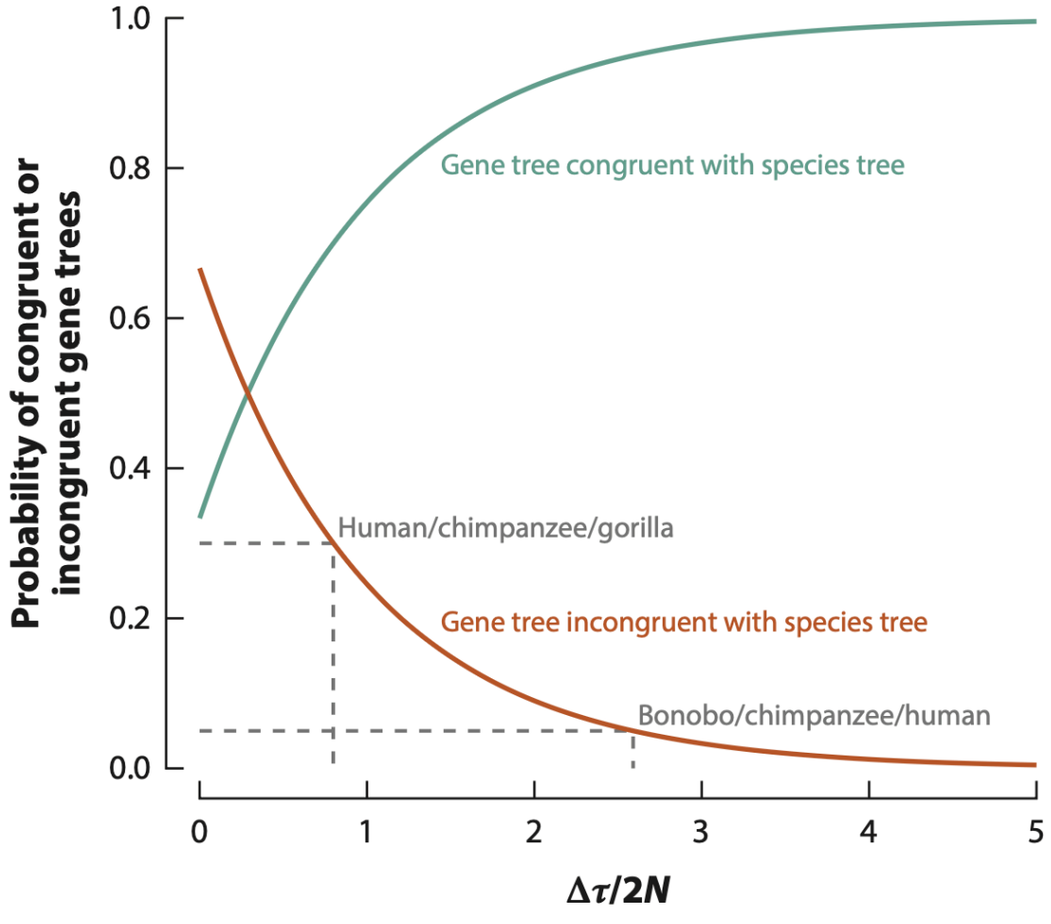

k remaining lineages at time τ
Initial sample of n genes at time zero

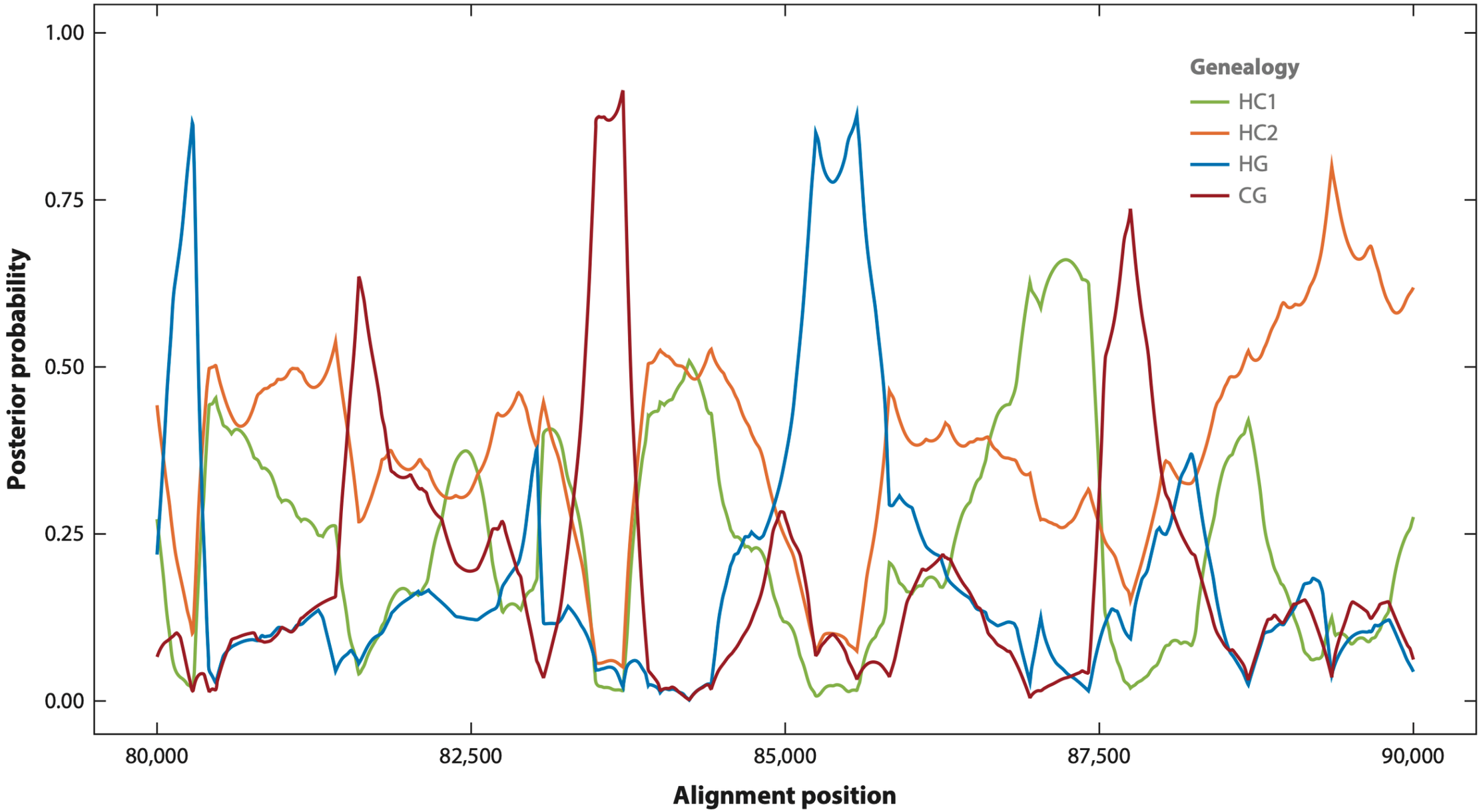

Density of having k lineages left
n = 5
k = 5
k = 4
k = 3
k = 2
n = 10
k = 10
k = 7
n = 25
k = 25
k = 15
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
2N generations back in time
0
0.5
1
1.5
2
Millions of years ago with N = 10,000 and a generation time of 25 years

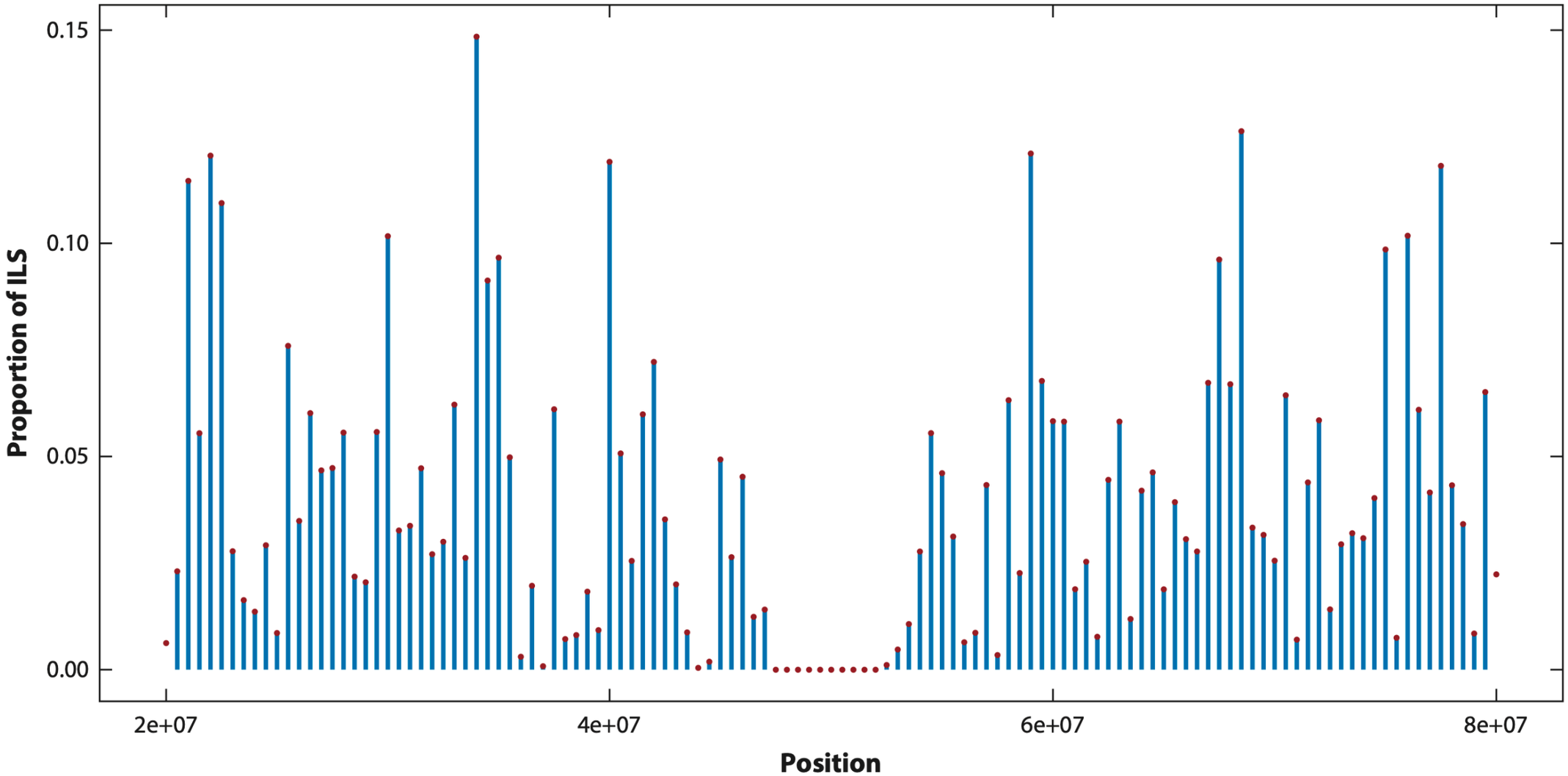

Probability that all lineages have coalesced
1.0
0.8
0.6
0.4
0.2
0.0
Denisova/neanderthal
Human/neanderthal
Bornean/Sumatran orangutans
Bonobo/ chimpanzee
n = 2
n = 5
n = 10
n = 15
n = 25
0
1
2
3
4
2N generations back in time
0
0.5
1
1.5
2
Millions of years ago with N = 10,000 and a generation time of 25 years


Probability that all lineages have coalesced
1.0
0.8
0.6
0.4
0.2
0.0
τ = 3
τ = 2
τ = 1
0
10
20
30
40
50
n


(AB)C 2
(BC)A
(AC)B
(AB)C 1
t_2
t_1
$\Delta\tau = t_2 - t_1$
A
B
C


Probability of congruent or incongruent gene trees
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
$\Delta\tau/2N$
Gene tree congruent with species tree
Gene tree incongruent with species tree
Human/chimpanzee/gorilla
Bonobo/chimpanzee/human


Genealogy
HC1
HC2
HG
CG
1.00
0.75
0.50
0.25
0.00
Posterior probability
80,000
82,500
85,000
87,500
90,000
Alignment position


0.15
0.10
0.05
0.00
Proportion of ILS
2e+07
4e+07
6e+07
8e+07
Position

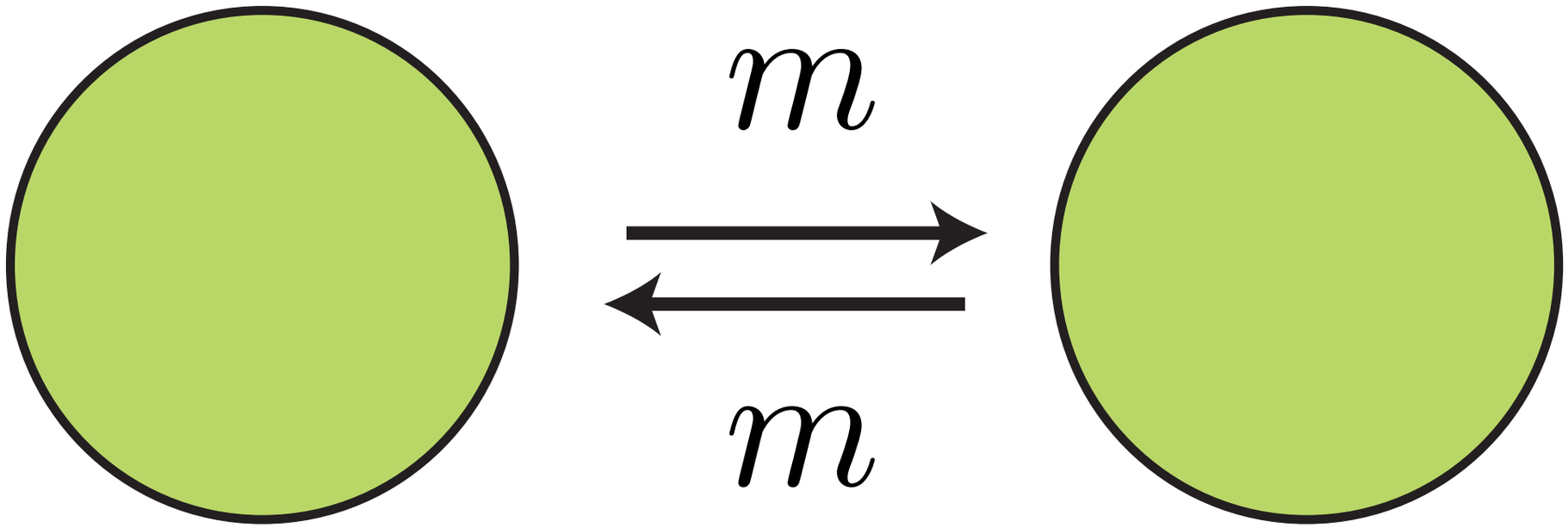
Population structure

Week

Kasper Munch

Population structure

Two populations



Samples from one population

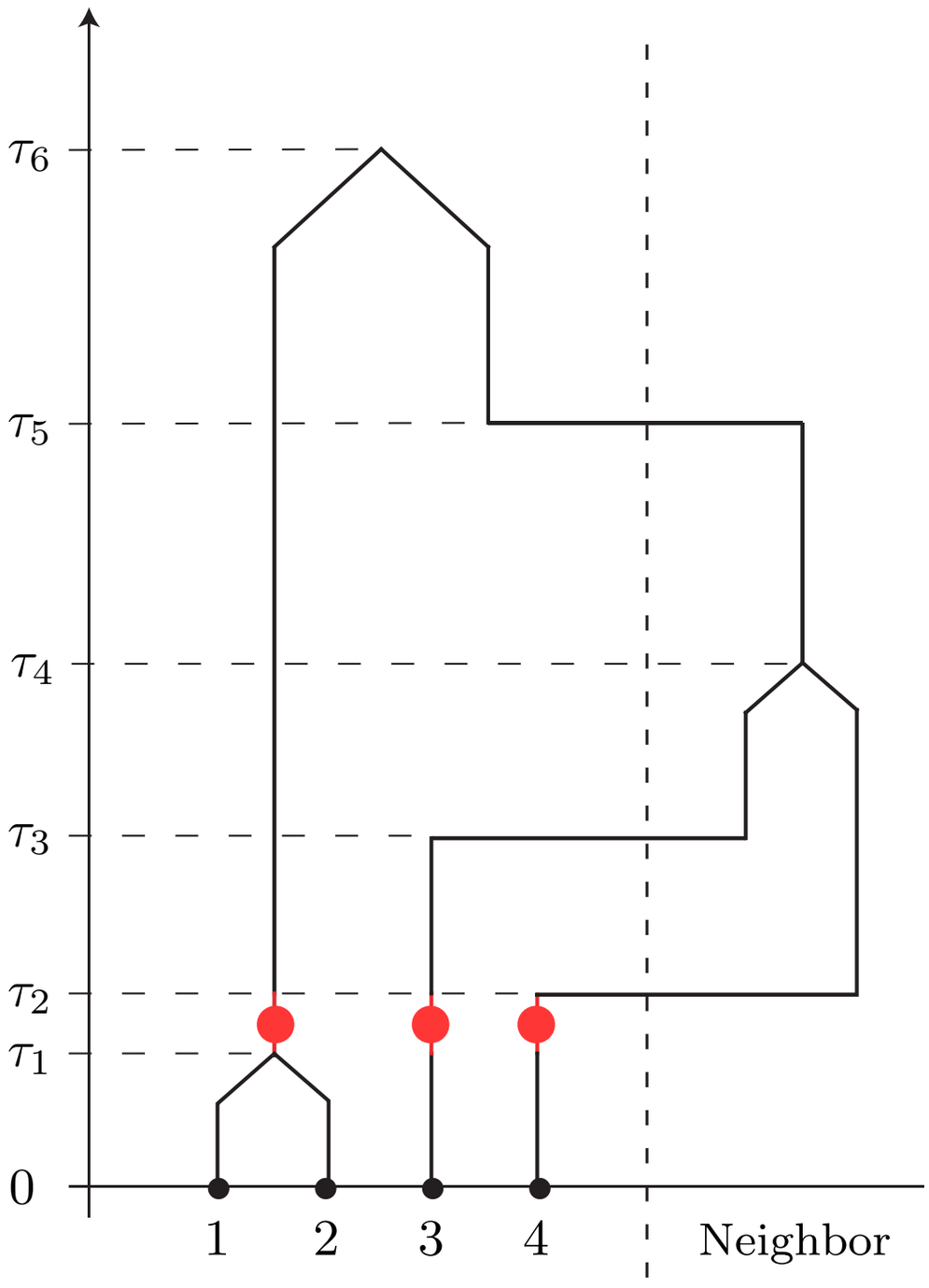
Competing rates

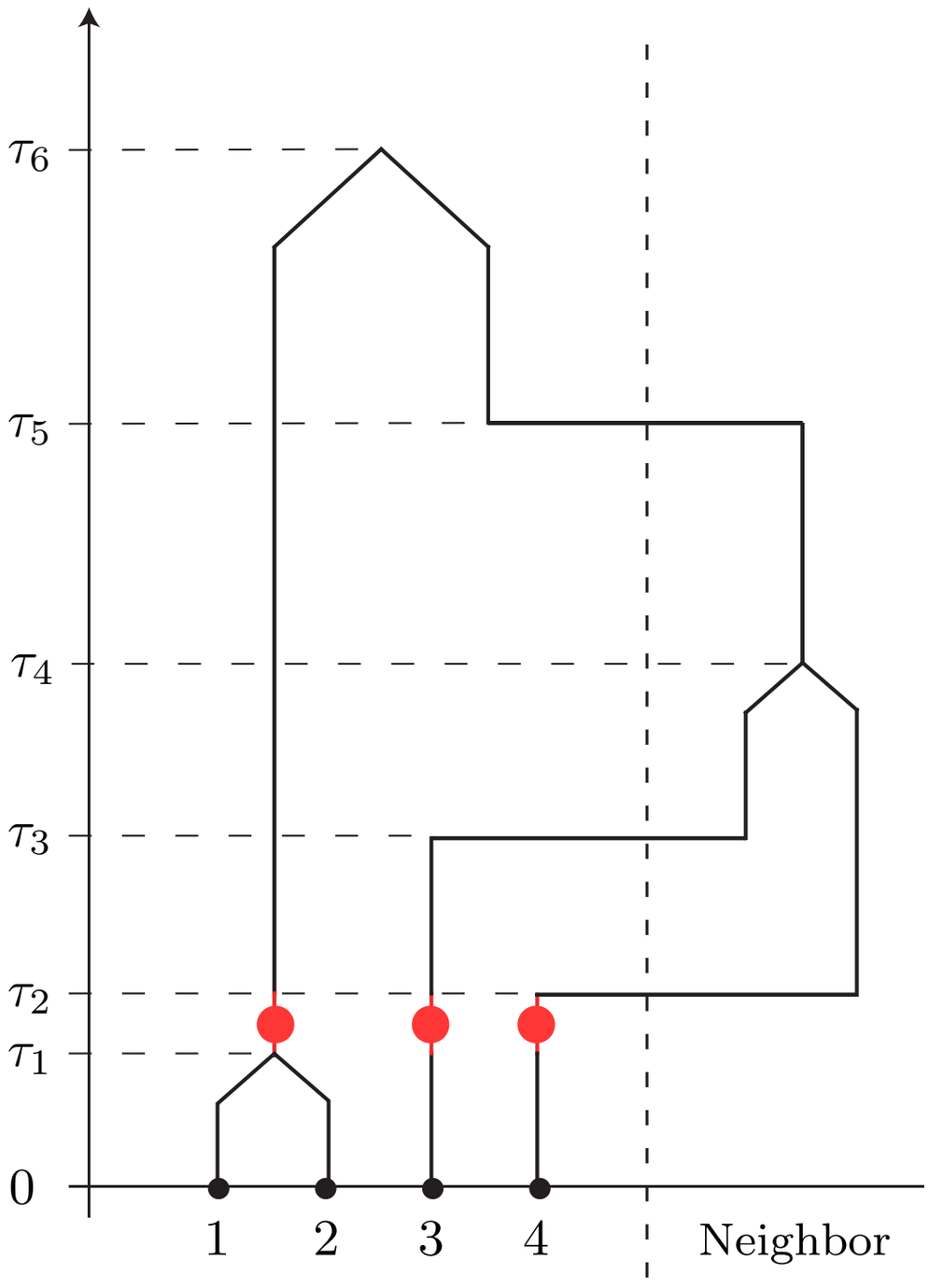
What happens and when

$$\text{Probability of any event} = \binom{n}{2}\frac{1}{2N} + nm$$

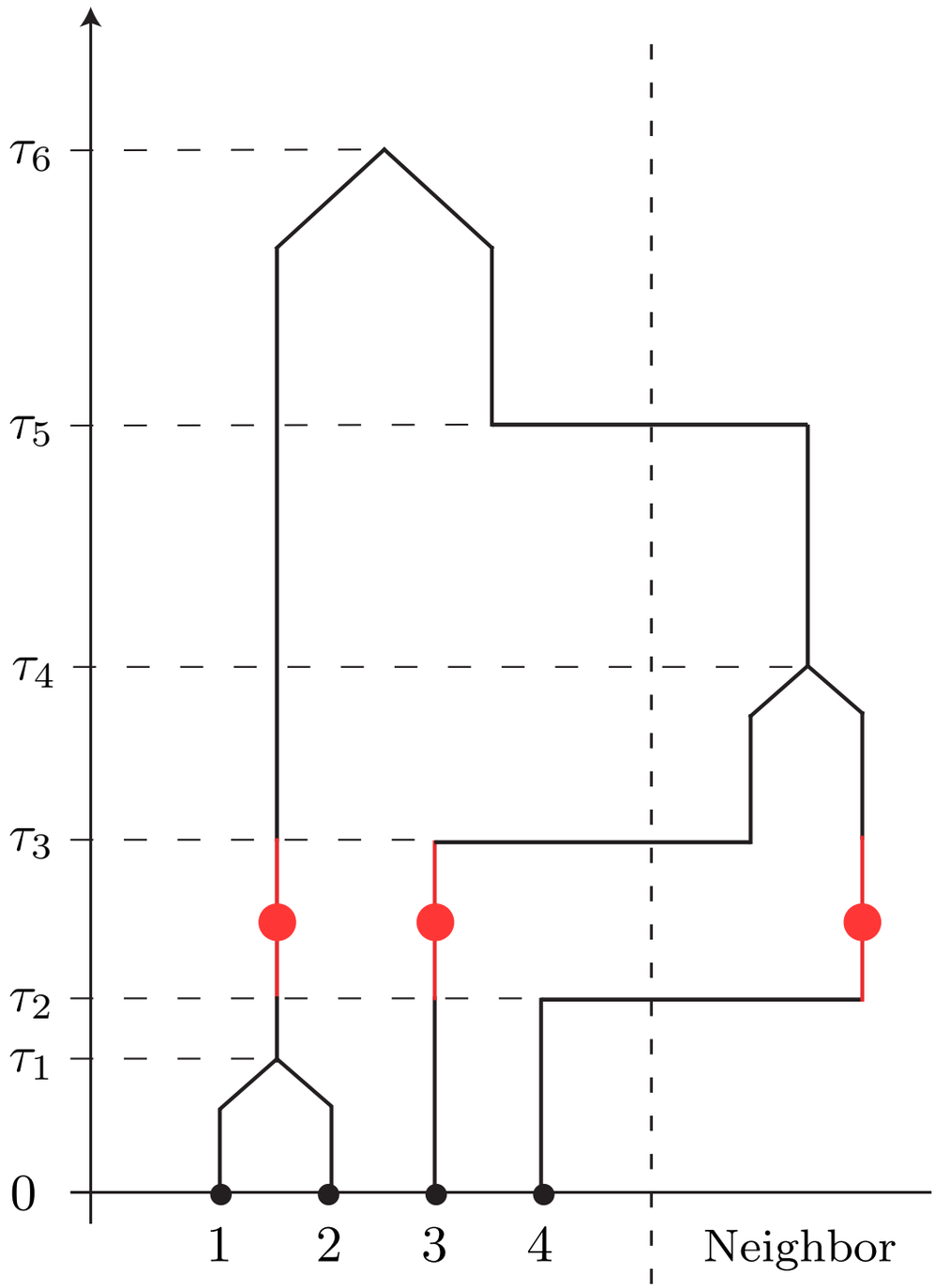
$$\text{Probability that a coalescent occurs first} = \frac{\binom{n}{2}\frac{1}{2N}}{\binom{n}{2}\frac{1}{2N} + nm} = \frac{n-1}{n-1+4Nm}$$

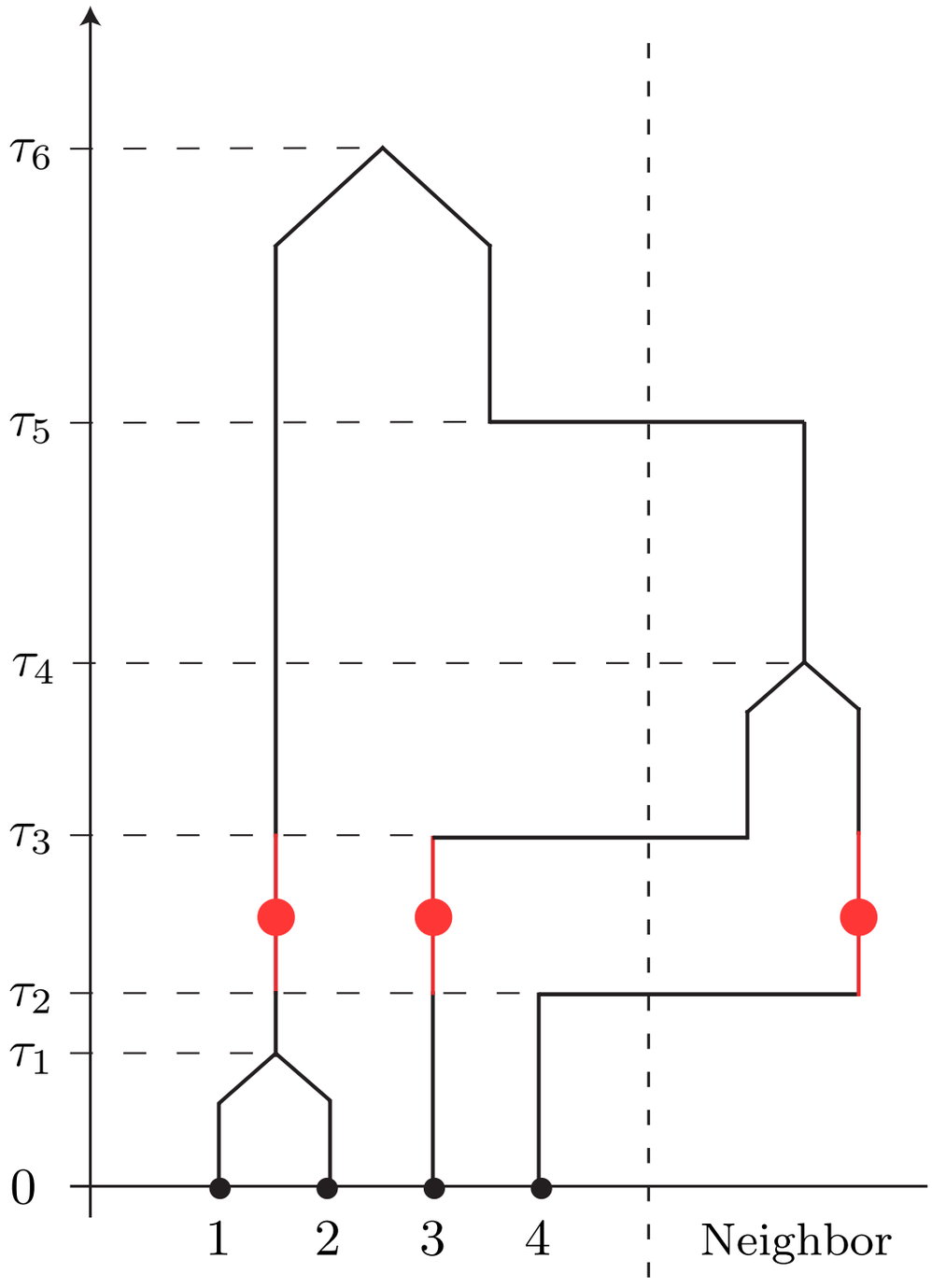
$$\text{Probability that a migration occurs first} = \frac{nm}{\binom{n}{2}\frac{1}{2N} + nm} = \frac{4Nm}{n-1+4Nm}$$


τ_6
τ_5
τ_4
τ_3
τ_2
τ_1
0
1
2
3
4
Neighbor

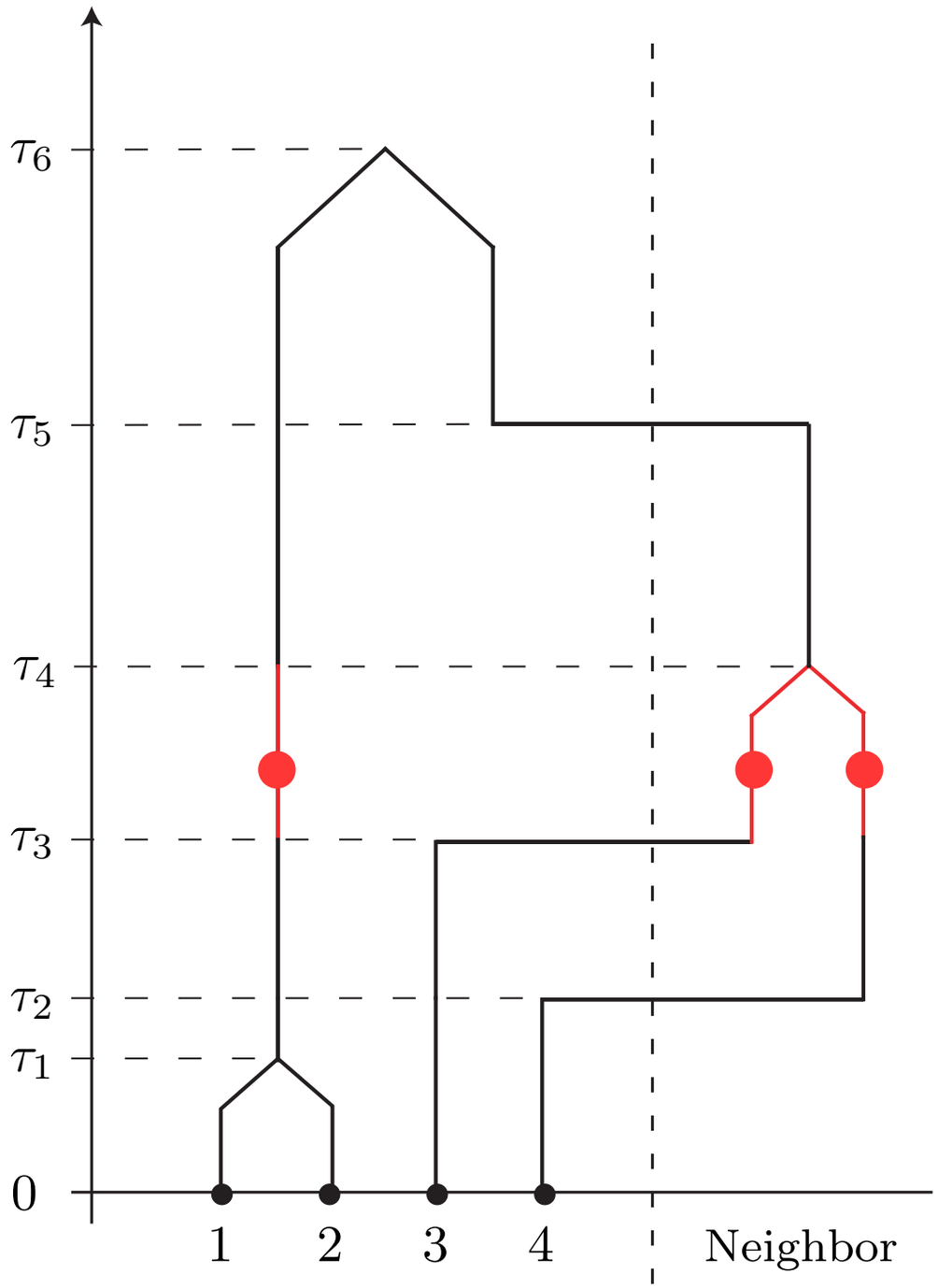


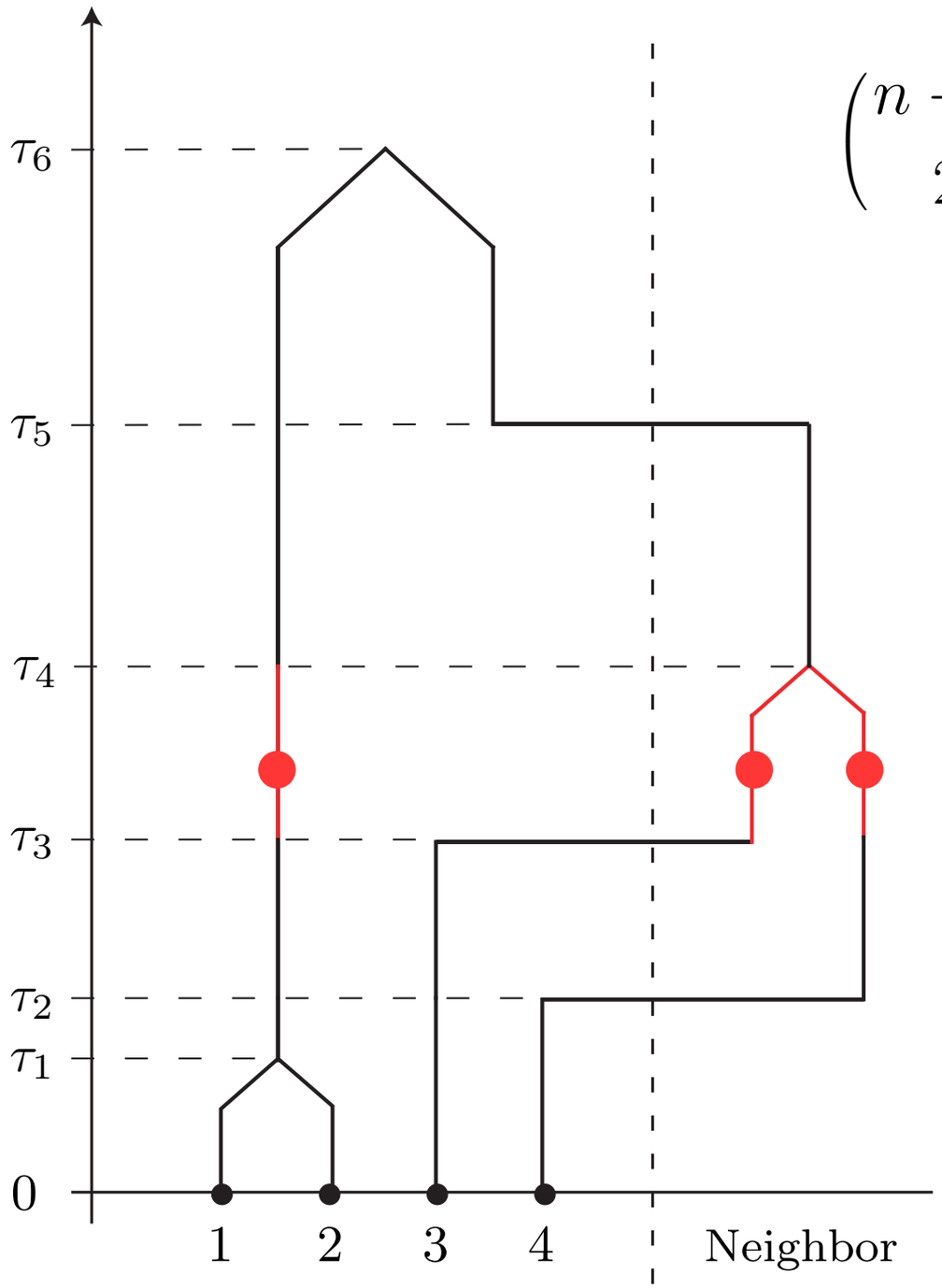
$$\binom{n-1}{2}\frac{1}{2N} + (n-1)m$$


τ_6
τ_5
τ_4
τ_3
τ_2
τ_1
0
1
2
3
4
Neighbor

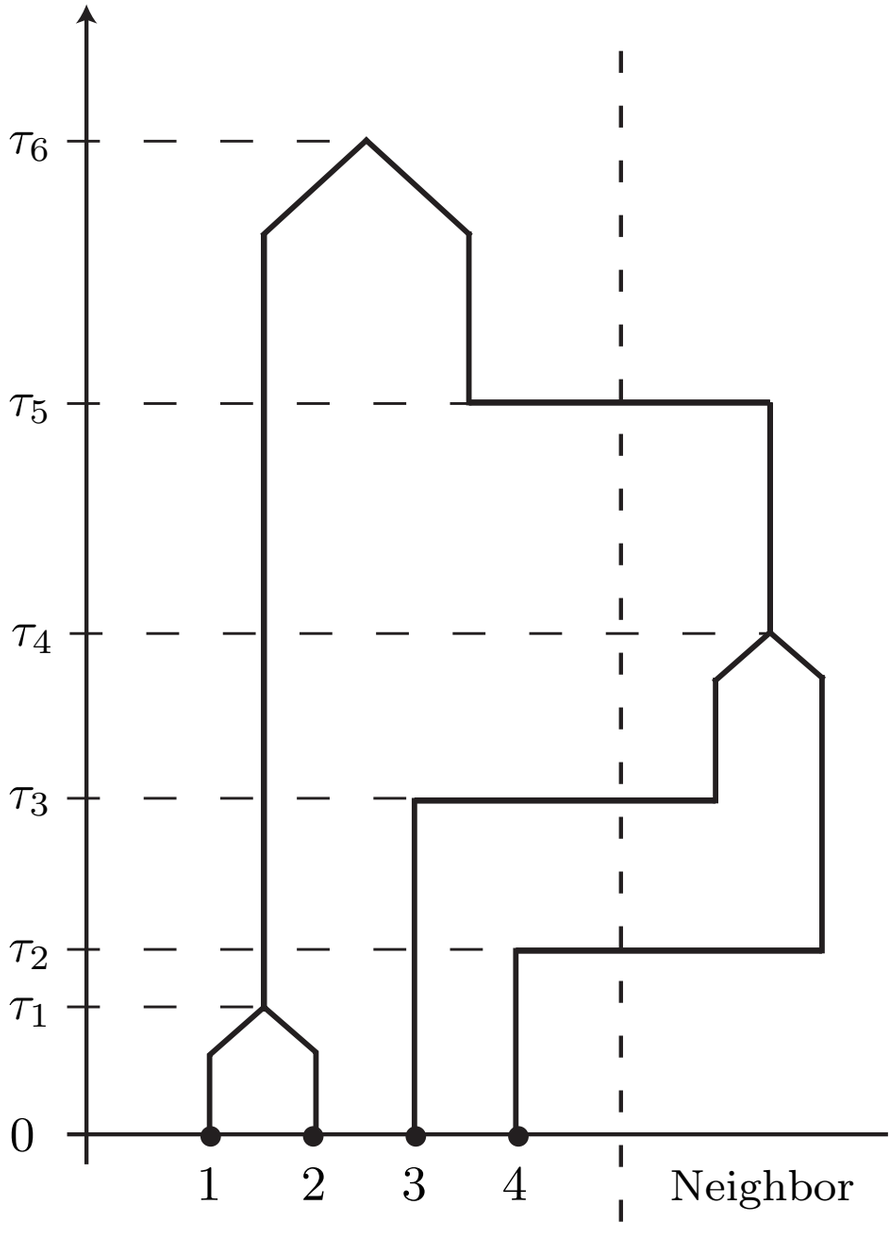


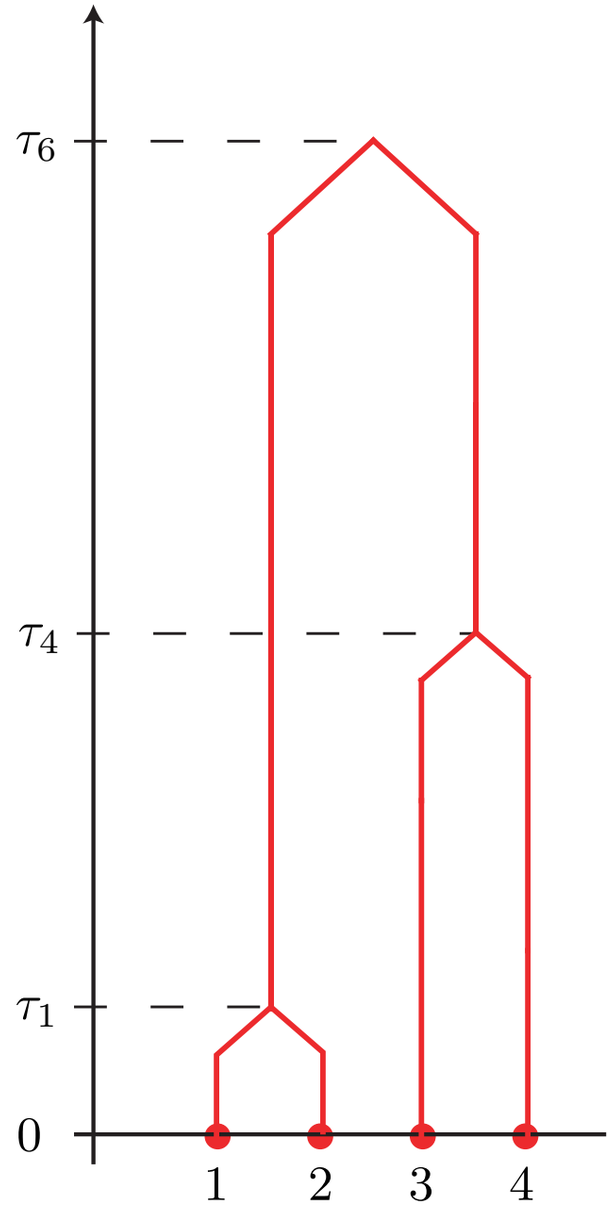
$$\binom{n-2}{2}\frac{1}{2N}+(n-2)m+m'$$


τ_6
τ_5
τ_4
τ_3
τ_2
τ_1
0
1
2
3
4
Neighbor

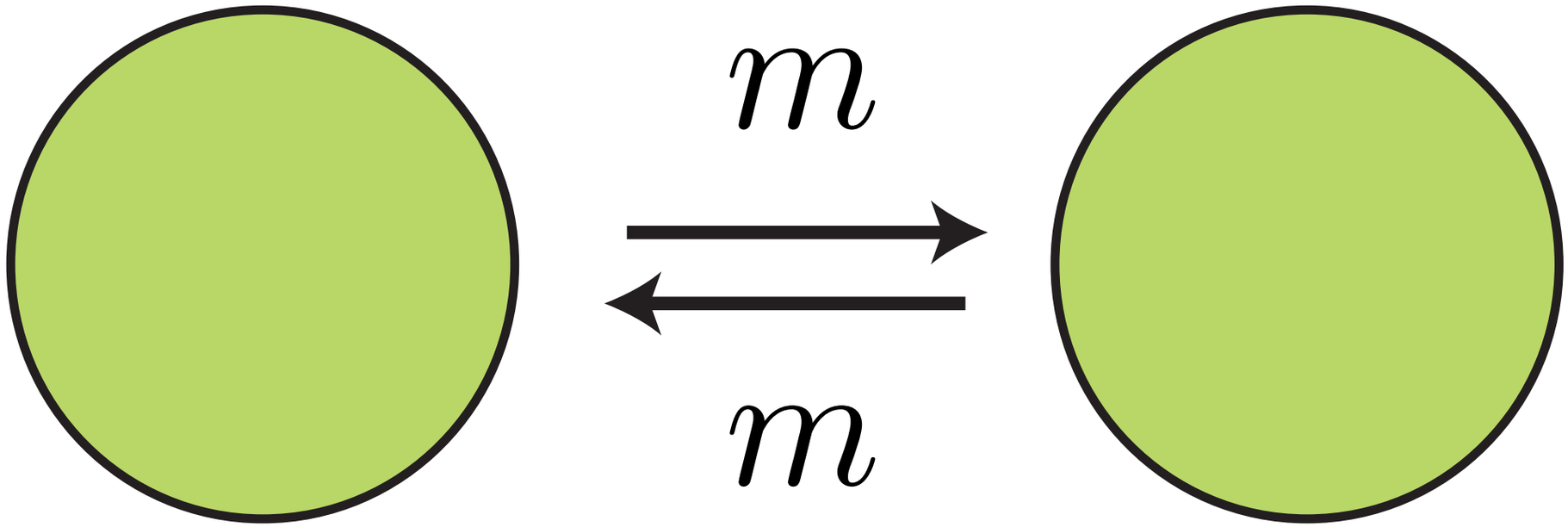


$$\binom{n-3}{2}\frac{1}{2N} + (n-3)m + 2m' + \binom{2}{2}\frac{1}{2N'}$$


τ_6
τ_5
τ_4
τ_3
τ_2
τ_1
0
1
2
3
4
Neighbor


τ_6
τ_4
τ_1
0
1
2
3
4

The simplest possible case



Simple exact results

$$
\begin{aligned}
E[T_{20}] &= \frac{1}{1/2N + 2m} + \frac{2m}{1/2N + 2m} \times E[T_{11}] \\
E[T_{11}] &= \frac{1}{2m} + \frac{1}{2} \times E[T_{20}] + \frac{1}{2} \times E[T_{02}] \\
E[T_{02}] &= \frac{1}{1/2N + 2m} + \frac{2m}{1/2N + 2m} \times E[T_{11}]
\end{aligned}
$$

Surprisingly simple results

$$E[T_{20}] = 4N \qquad E[T_{11}] = 2N\frac{1+8Nm}{4Nm}$$