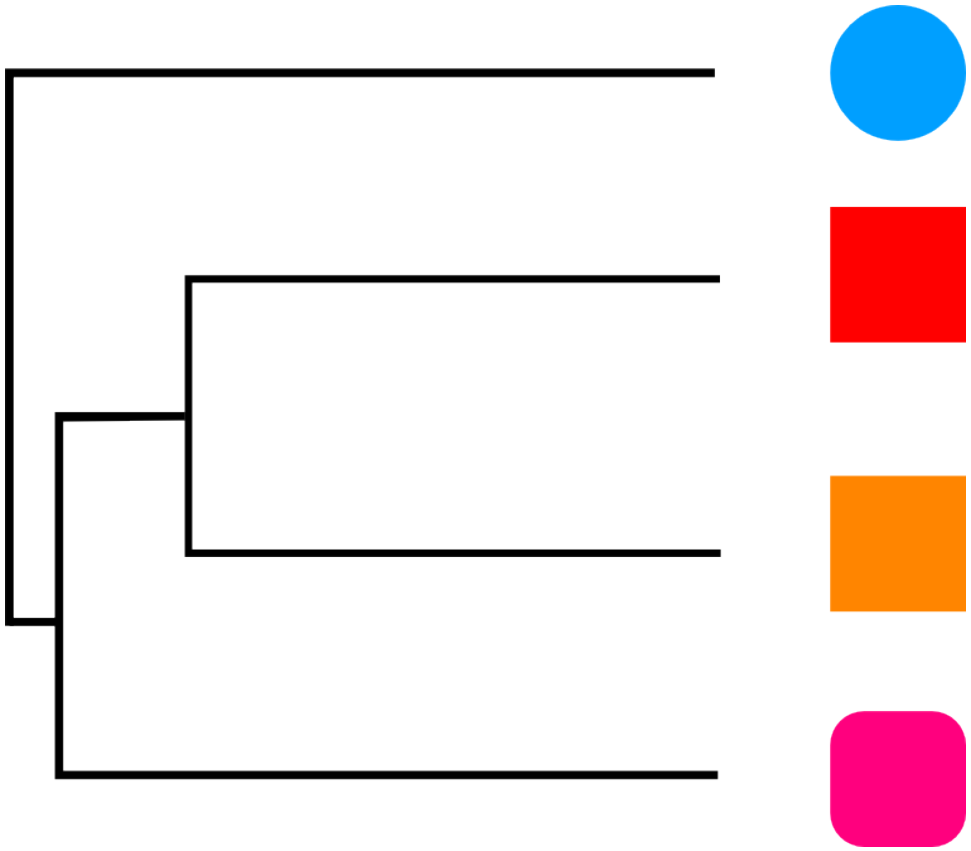
MDSC 308

Phylogenetics

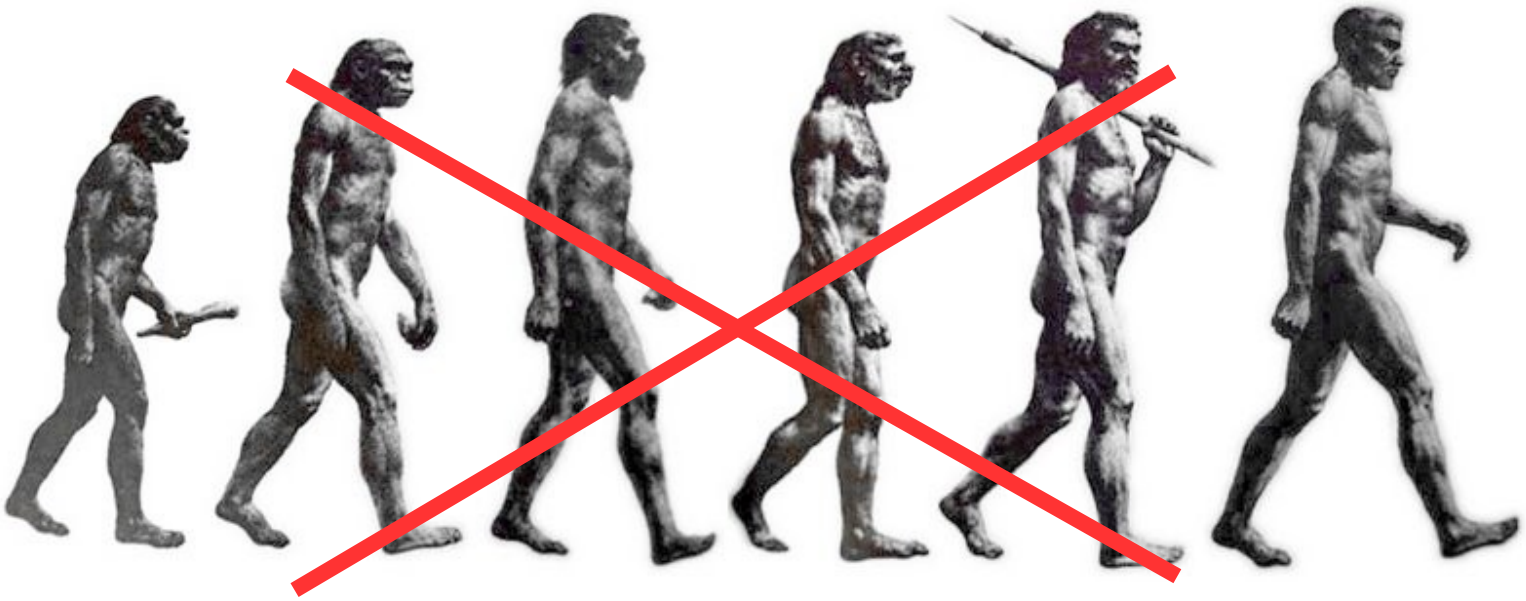
“Nothing in Biology Makes Sense Except in the Light of Evolution”

Theodosius Dobzhansky, 1973

Comparing things

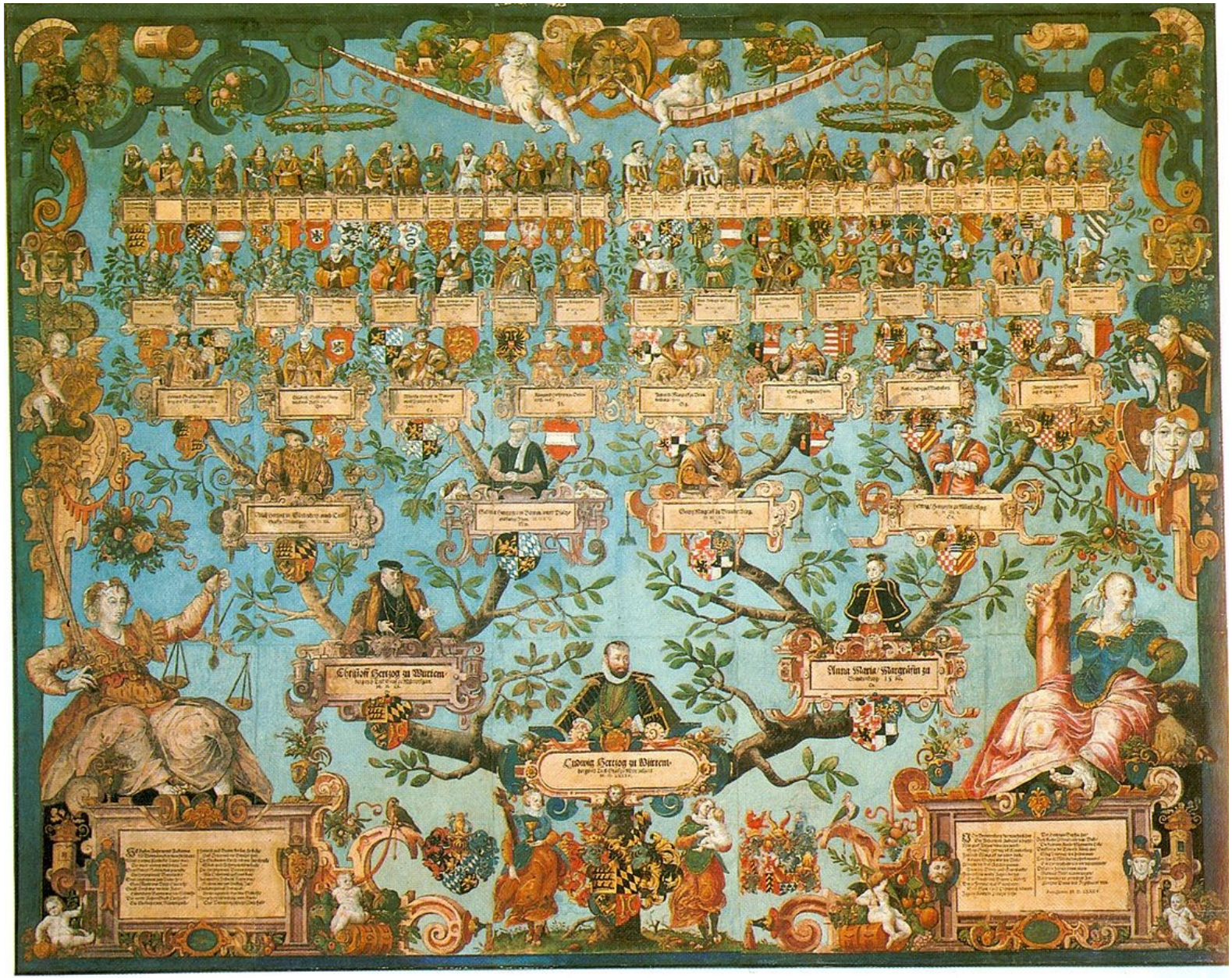


Evolution?



WRONG

Kingdom of Wurttemberg



Trees

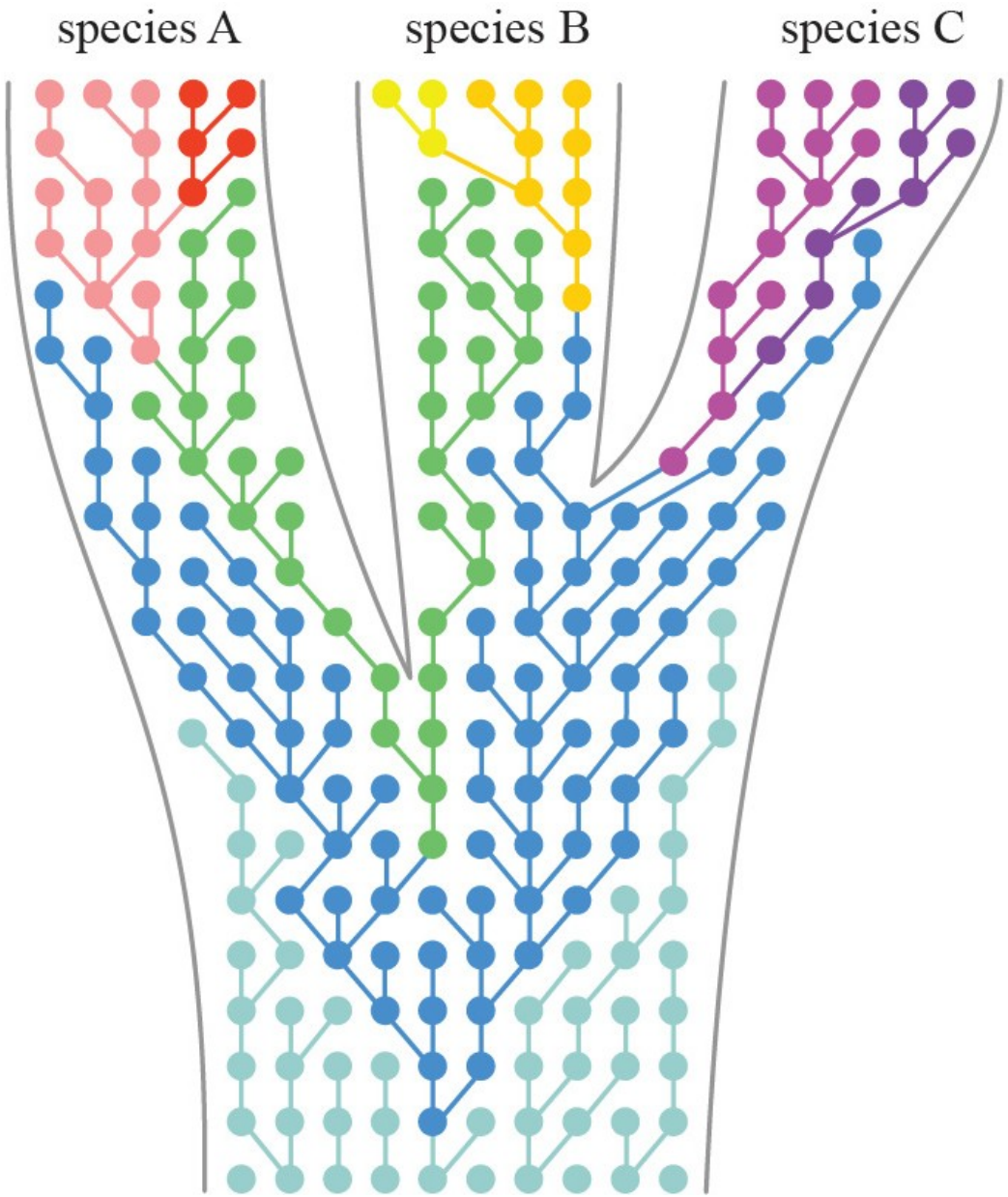
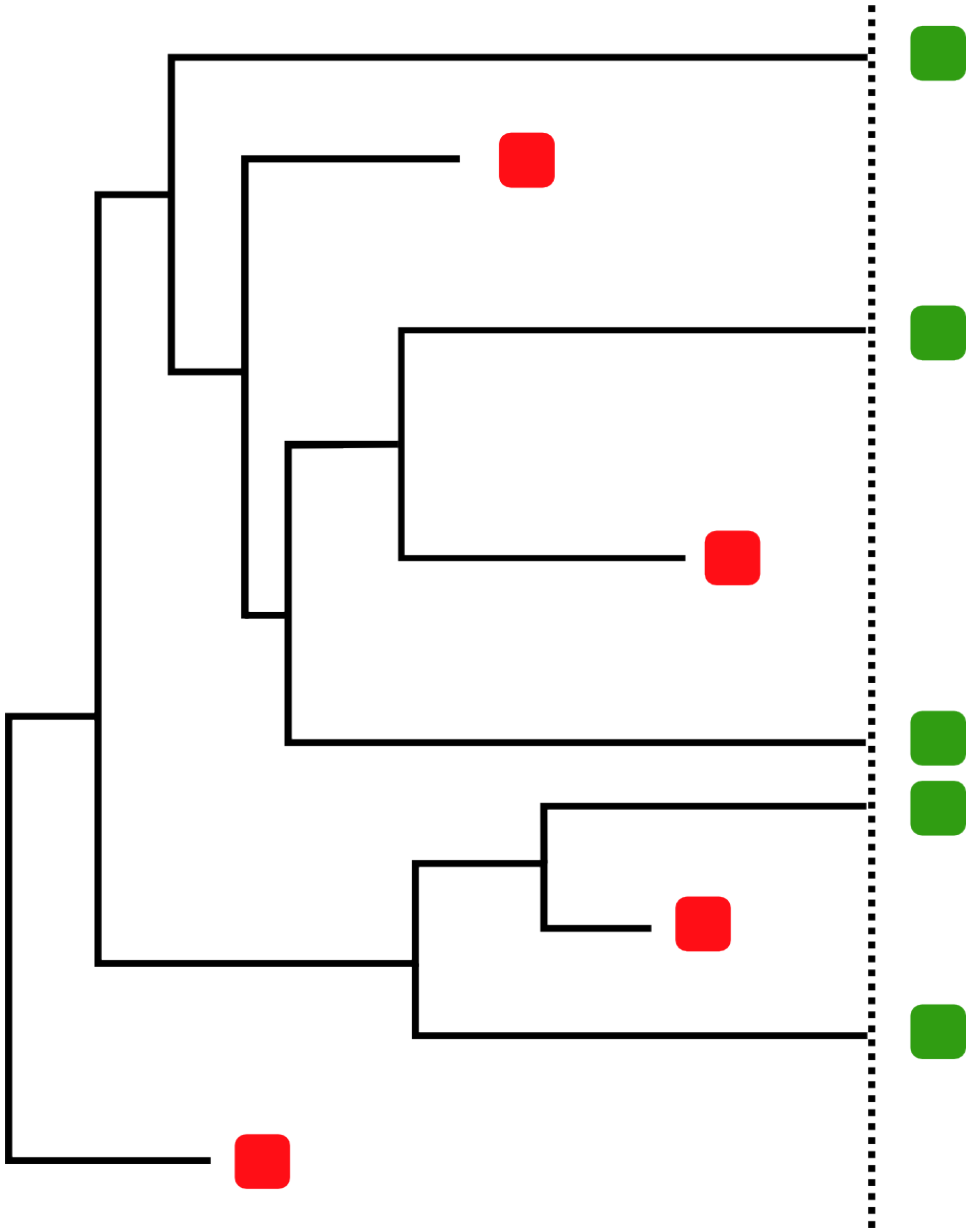
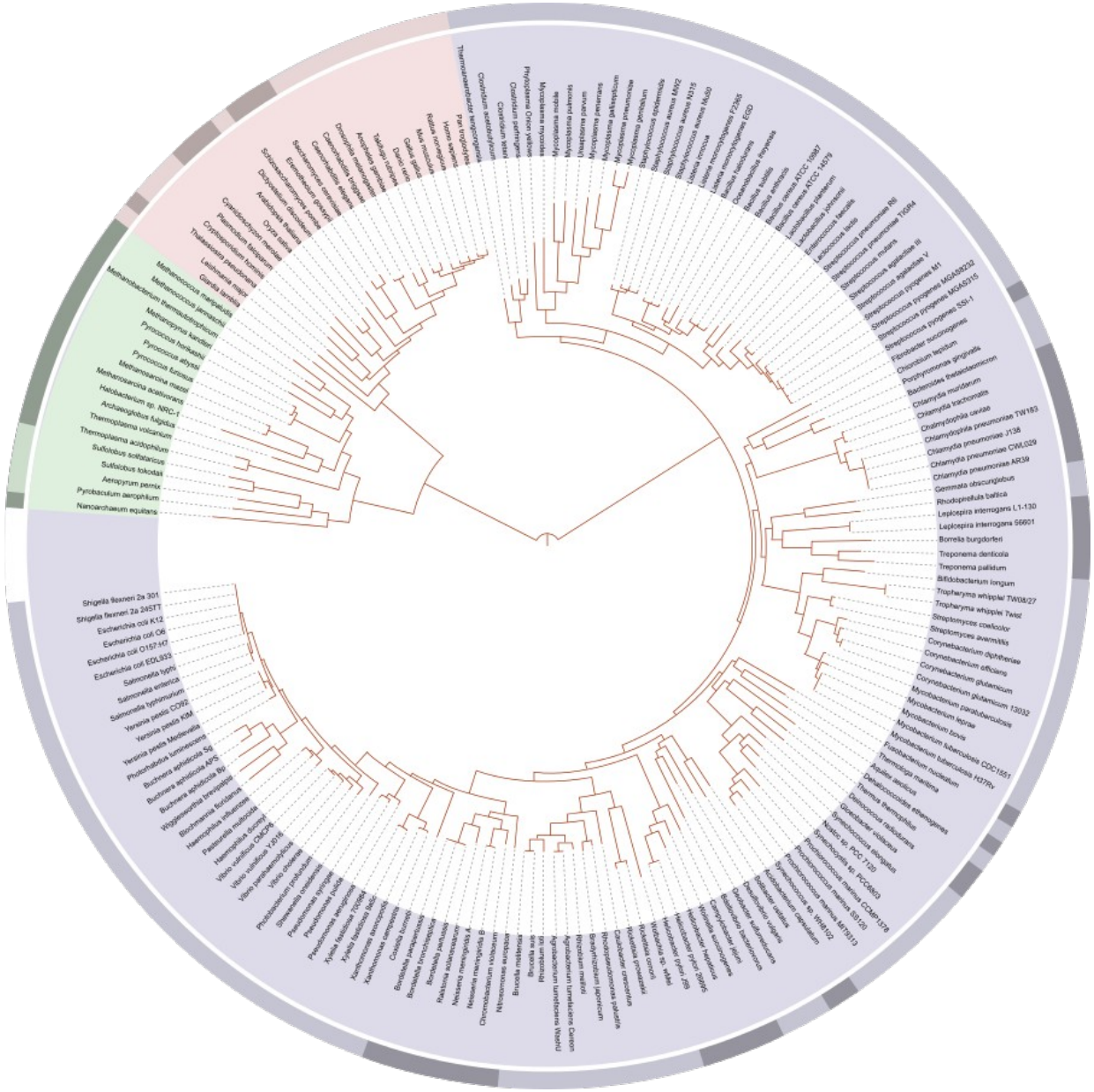


Figure author: Fredrick Leliaert

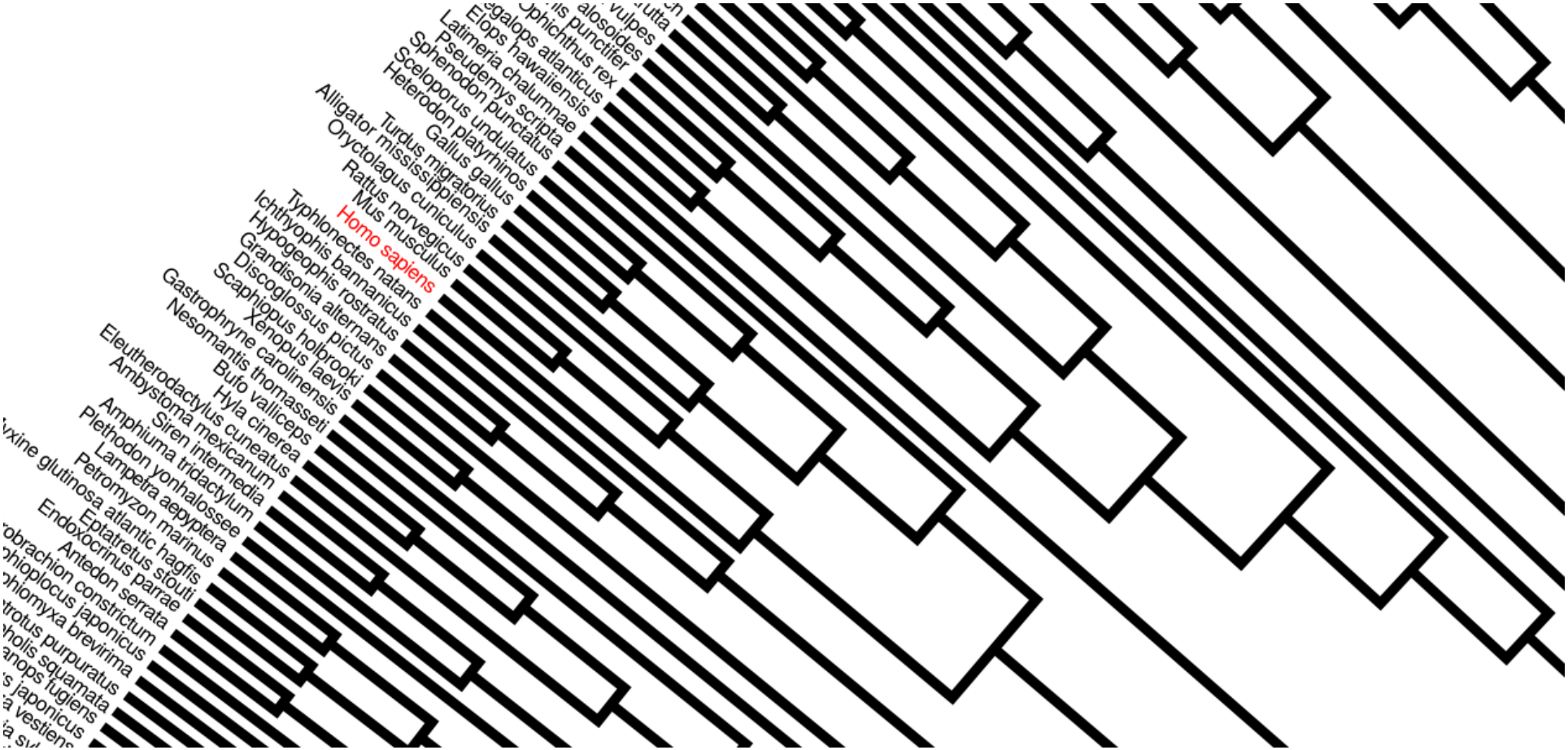
Extinction



Tree of life



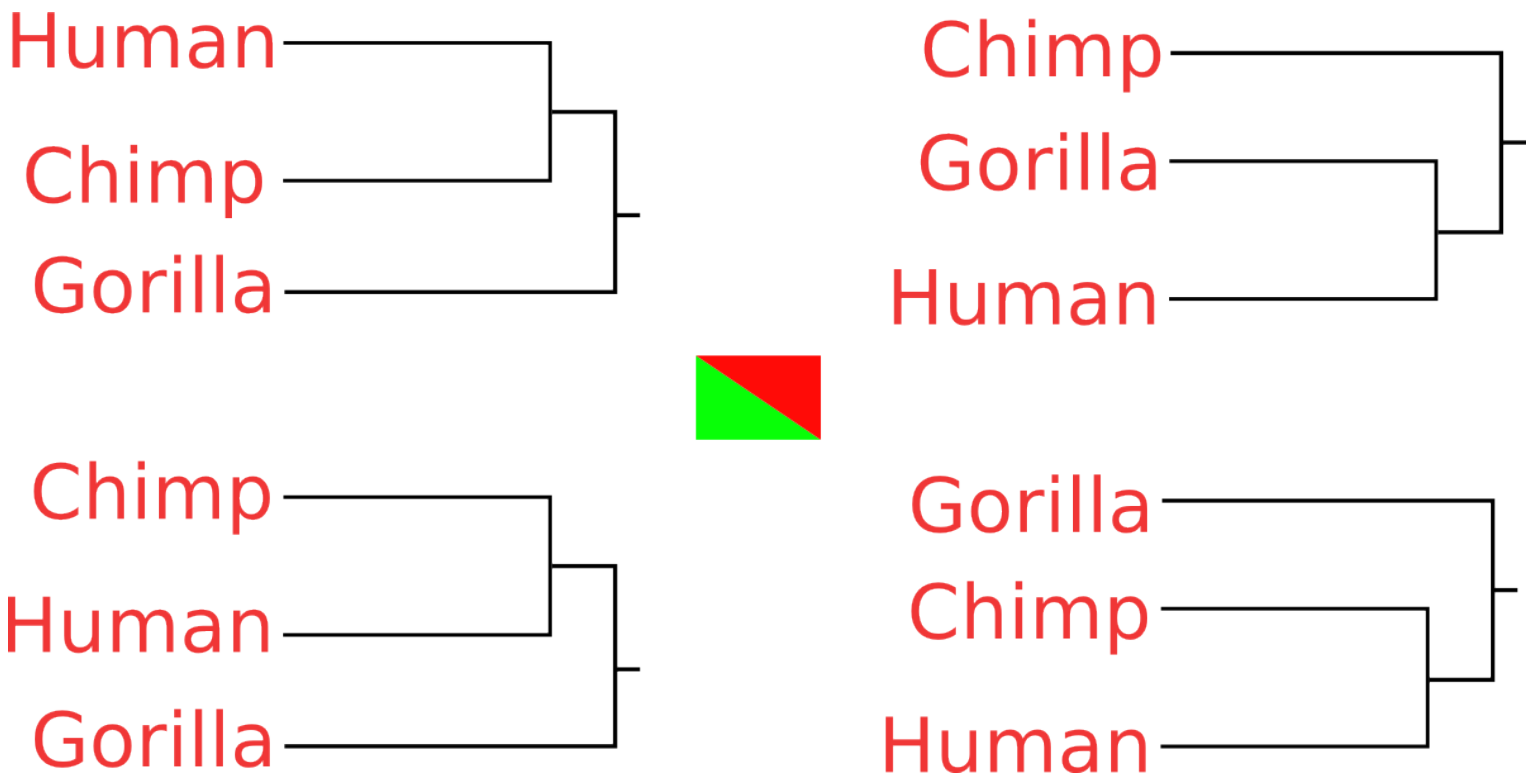
Tree of life



Mobiles

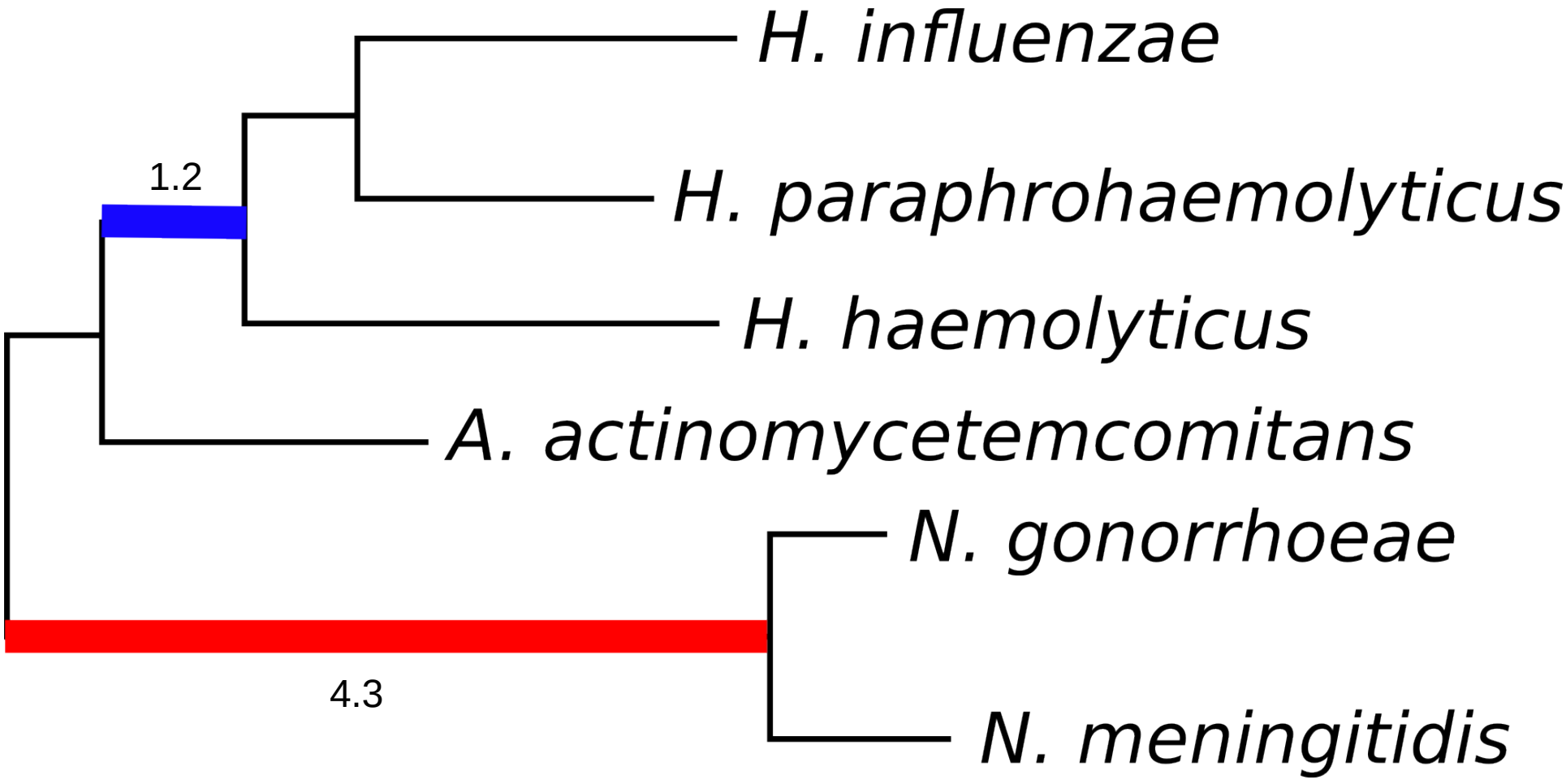
Mobiles

- There is no linear order
- Only branchings matter

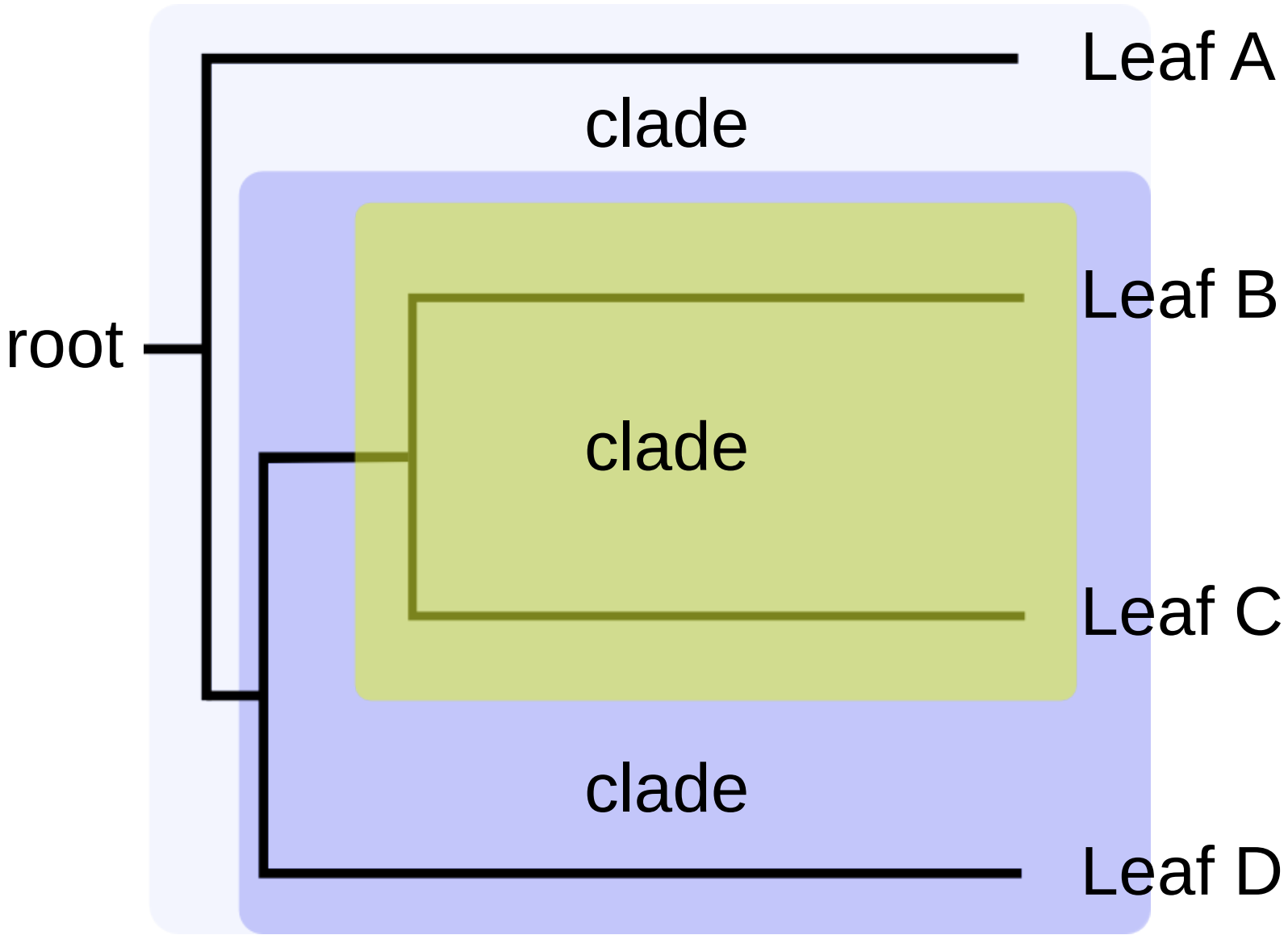


Branch length

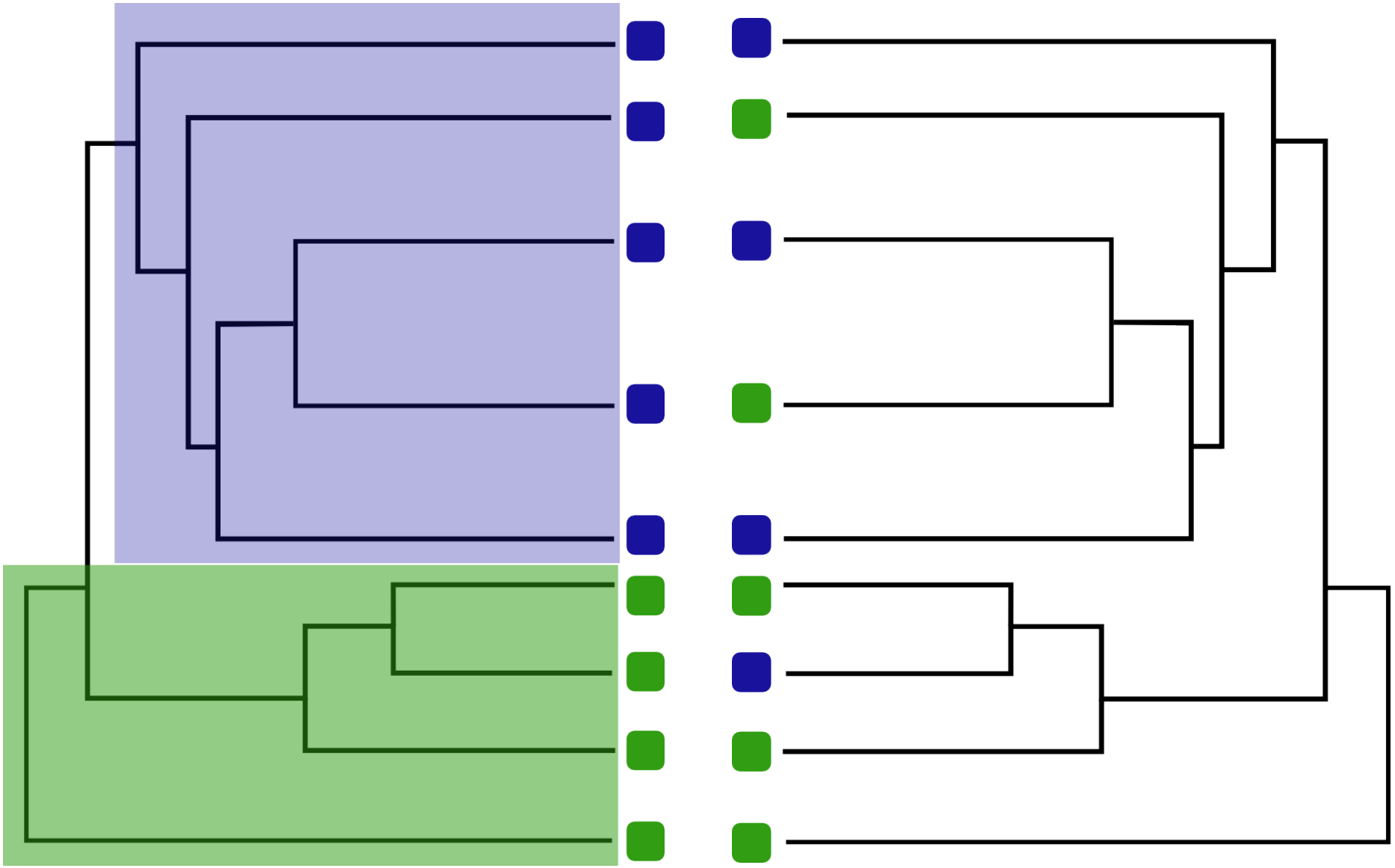
Distance = time * rate of substitutions



Jargon



Grouping



How many trees are there?

$$N_r = \prod_{k=2}^{T} (2k-3)$$

$$N_u = \prod_{k=3}^{T} (2k-5)$$

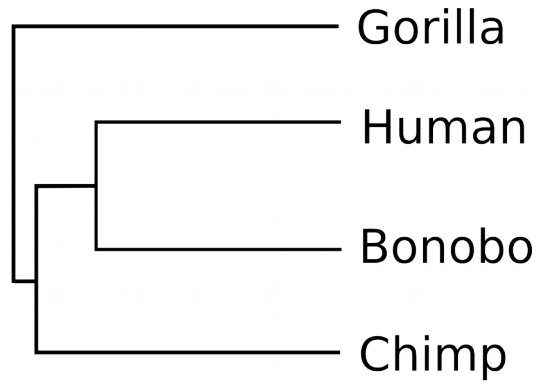
T	Unrooted	Rooted
10	2,027,025	3×10^{7}
15	7×10^{12}	2×10^{8}
20	2×10^{20}	8×10^{21}
100	2×10^{182}	2×10^{184}

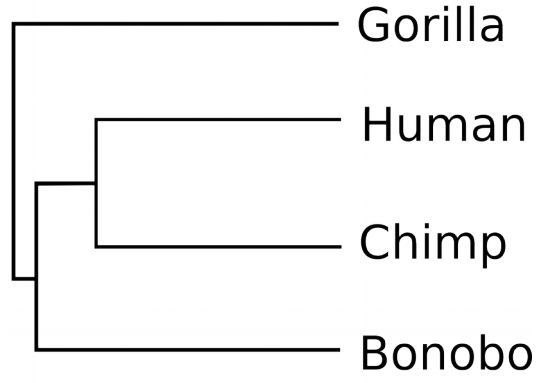
Ways to build a tree

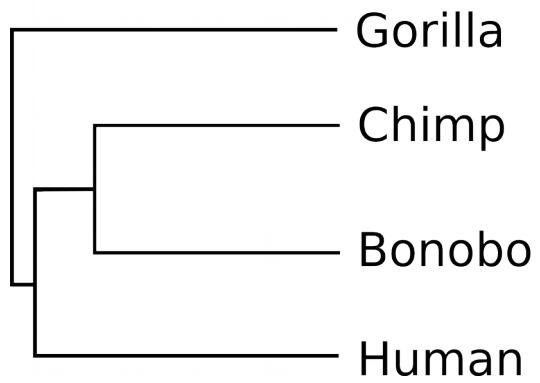
- Parsimony
  - Minimize number of mutations
  - Simple, but inaccurate
- Maximum Likelihood (most common)
  - Maximize probability of observation given model
  - Harder, but accurate
  - Does not provide confidence intervals
- Bayesian inference
  - Choose best model that maximizes probability given data
  - Hardest, very accurate
  - Explores all reasonable hypotheses

Parsimony

H: ACTGCATG
C: ACGGCCTC
G: CCGGCATG
B: ACTGCCTC







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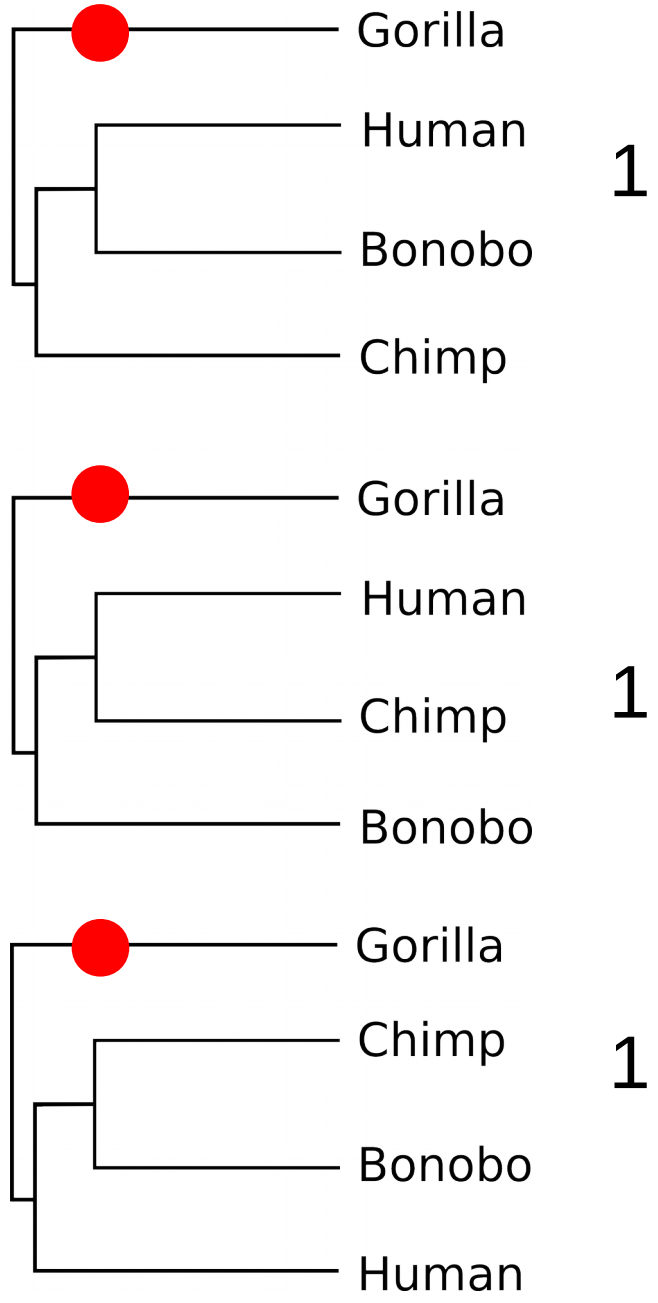

Parsimony

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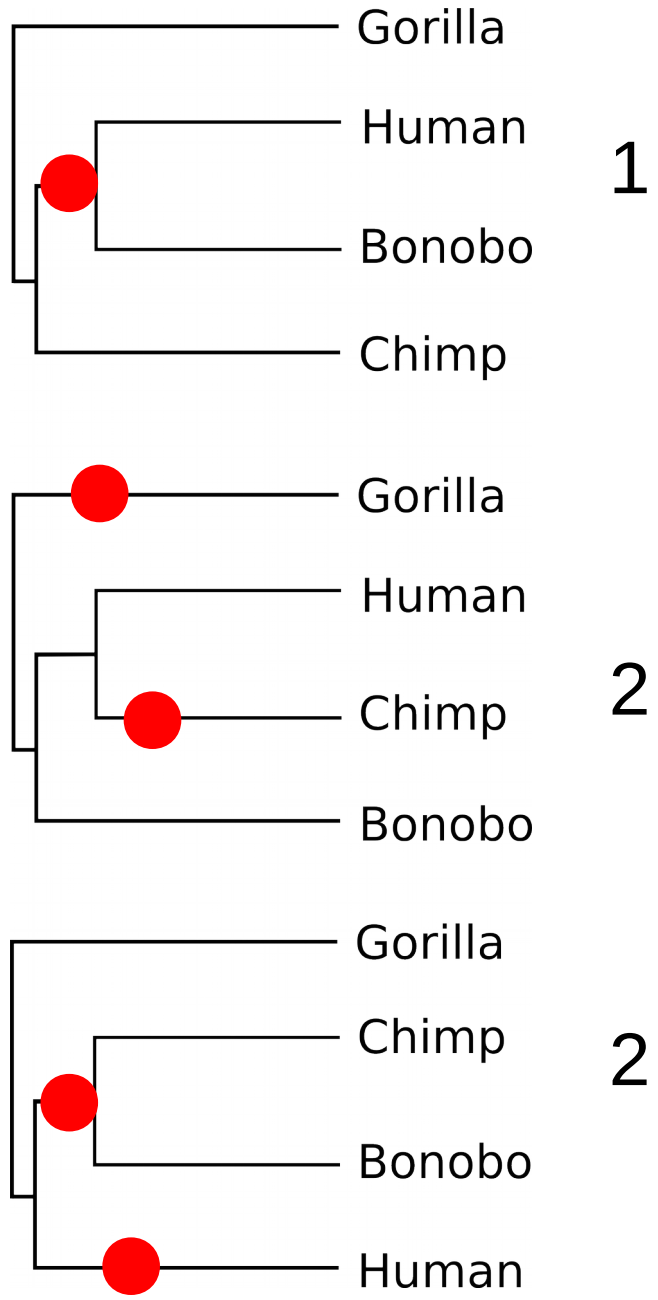

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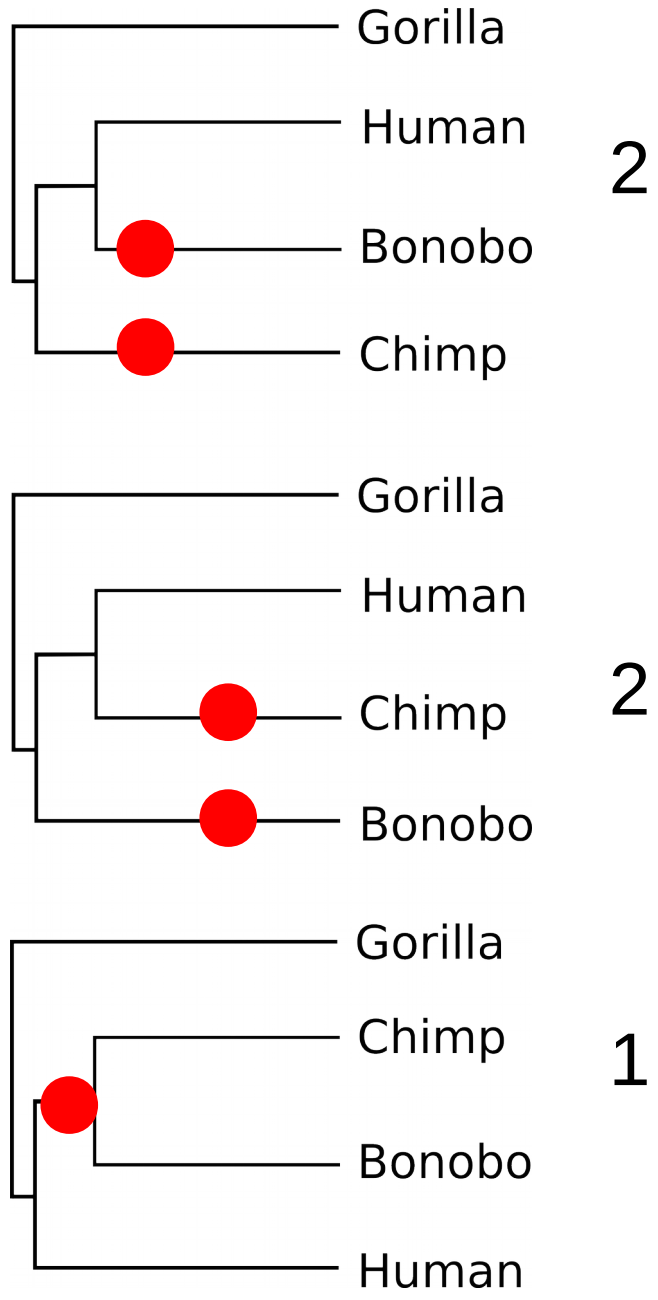

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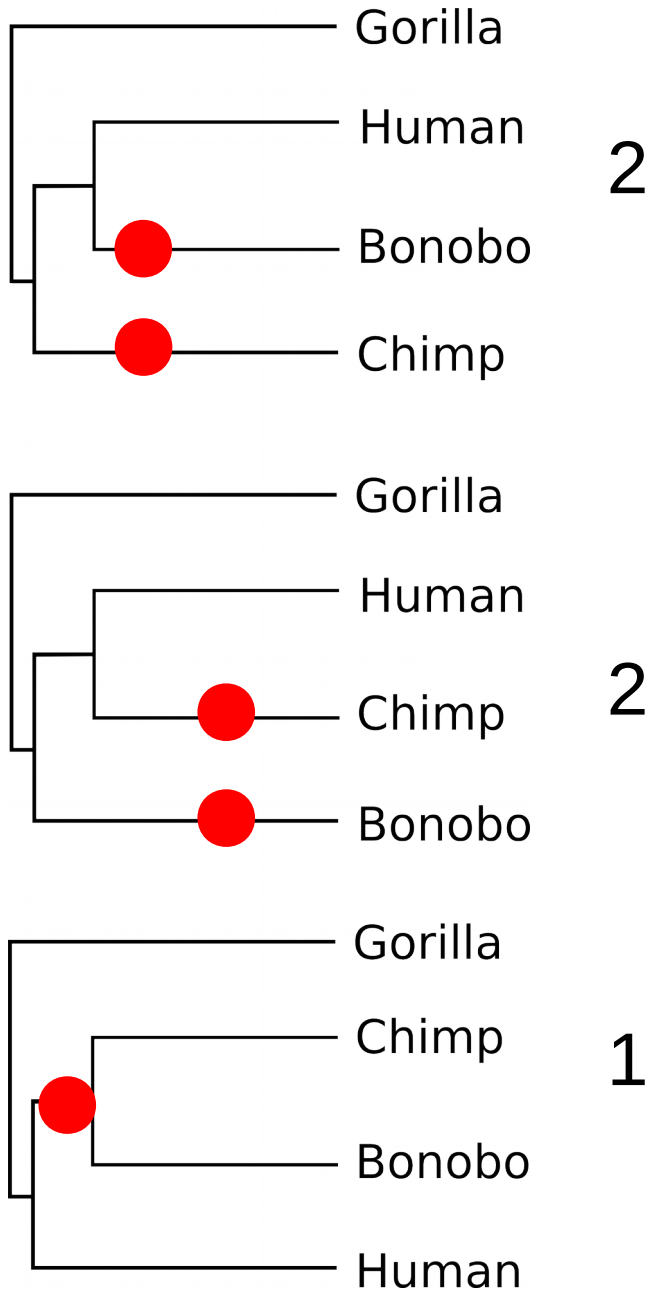

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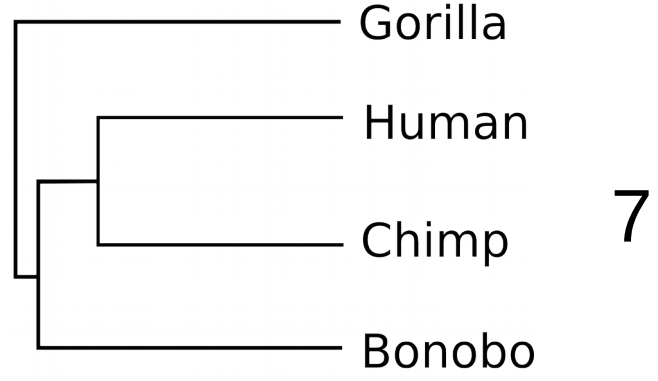

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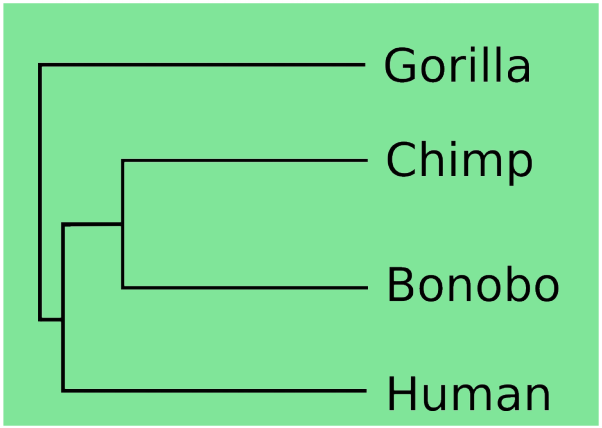


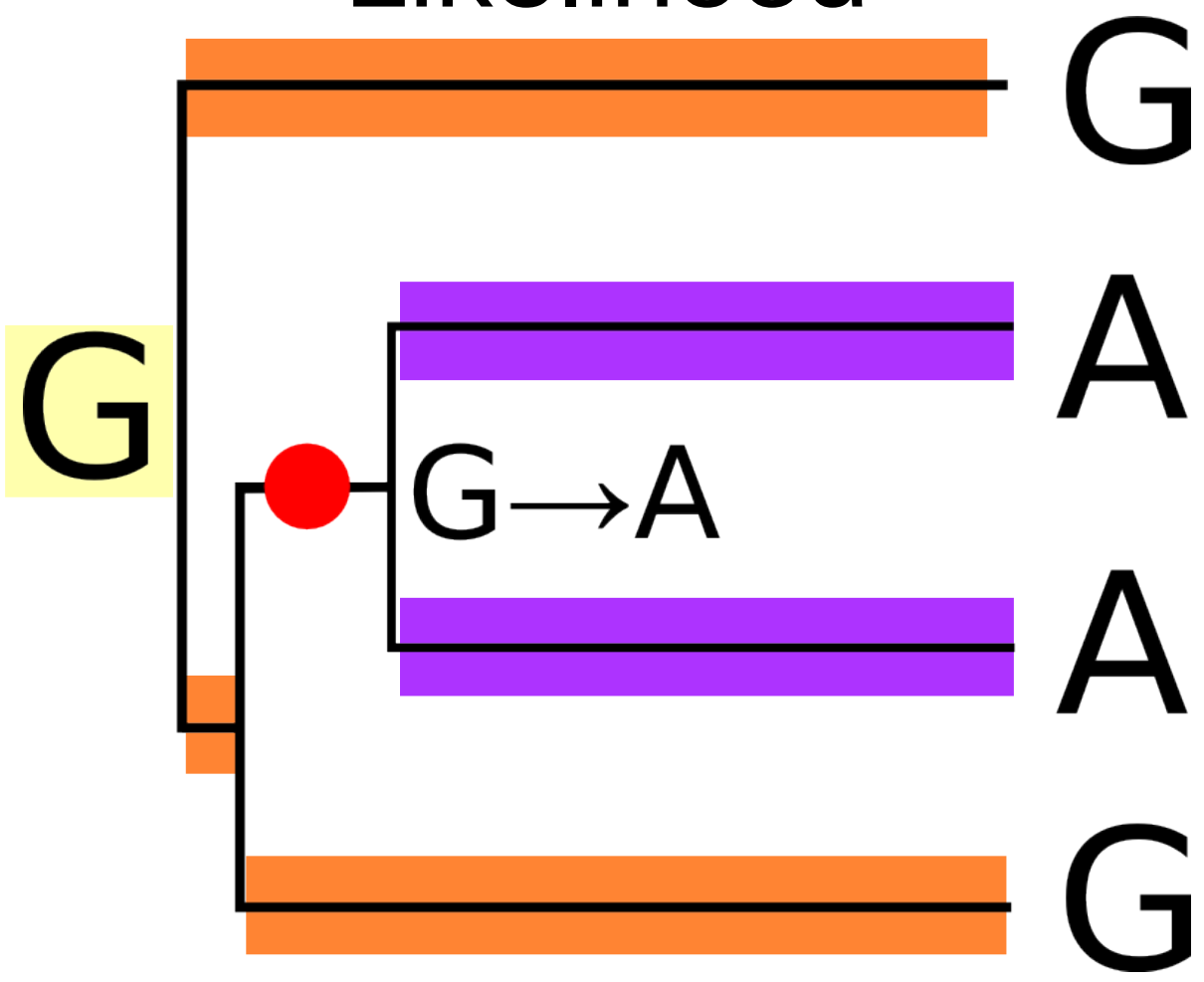
5

Likelihood

- Calculate the probability of each event according to a model
- Need to do this for all substitution histories
- Kimura 2 parameter model
  - Transition rate *a*
  - Transversion rate *b*

	A	C	T	G
A		b	a	b
C	b		b	a
T	a	b		b
G	b	a	b	

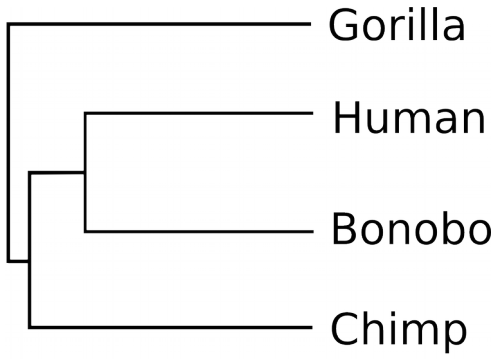
Likelihood

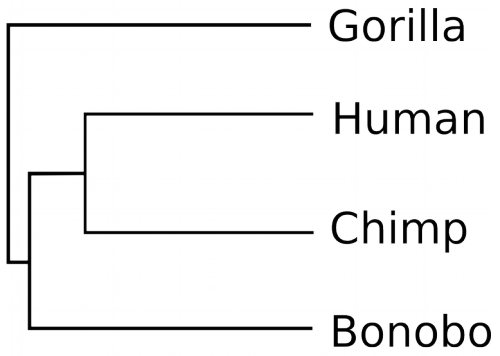


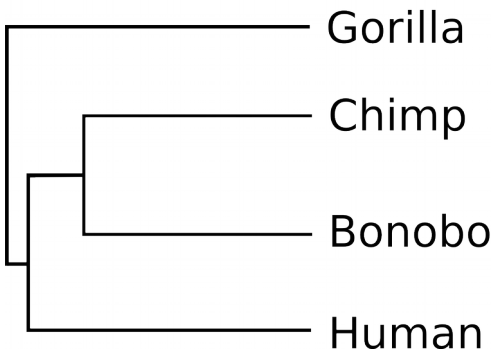
$$P(T) = P(G) \times P(G \to G) \times P(G \to G) \times P(G \to G) \times P(G \to A) \times P(A \to A) \times P(A \to A)$$

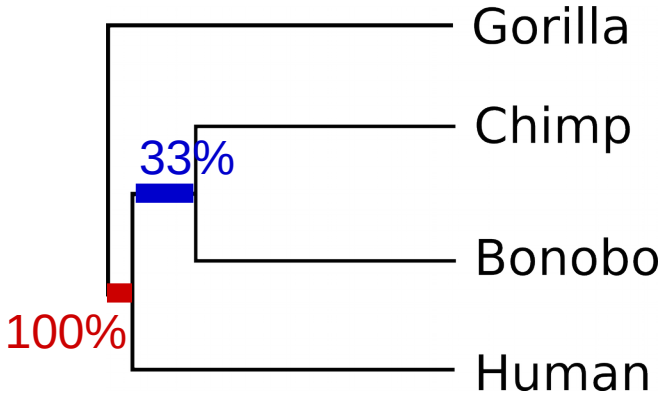
Bootstrap

```
H: ACGCGTAT
C: ACGCCGCT
G: CCGCGGAT
B: ACGCCTCT

H: ATGGCTCA
C: AGCGCTCC
G: CGGGCTCA
B: ATCGCTCC

H: ACTGCATG
C: ACGGCCTC
G: CCGGCATG
B: ACTGCCTC
```









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