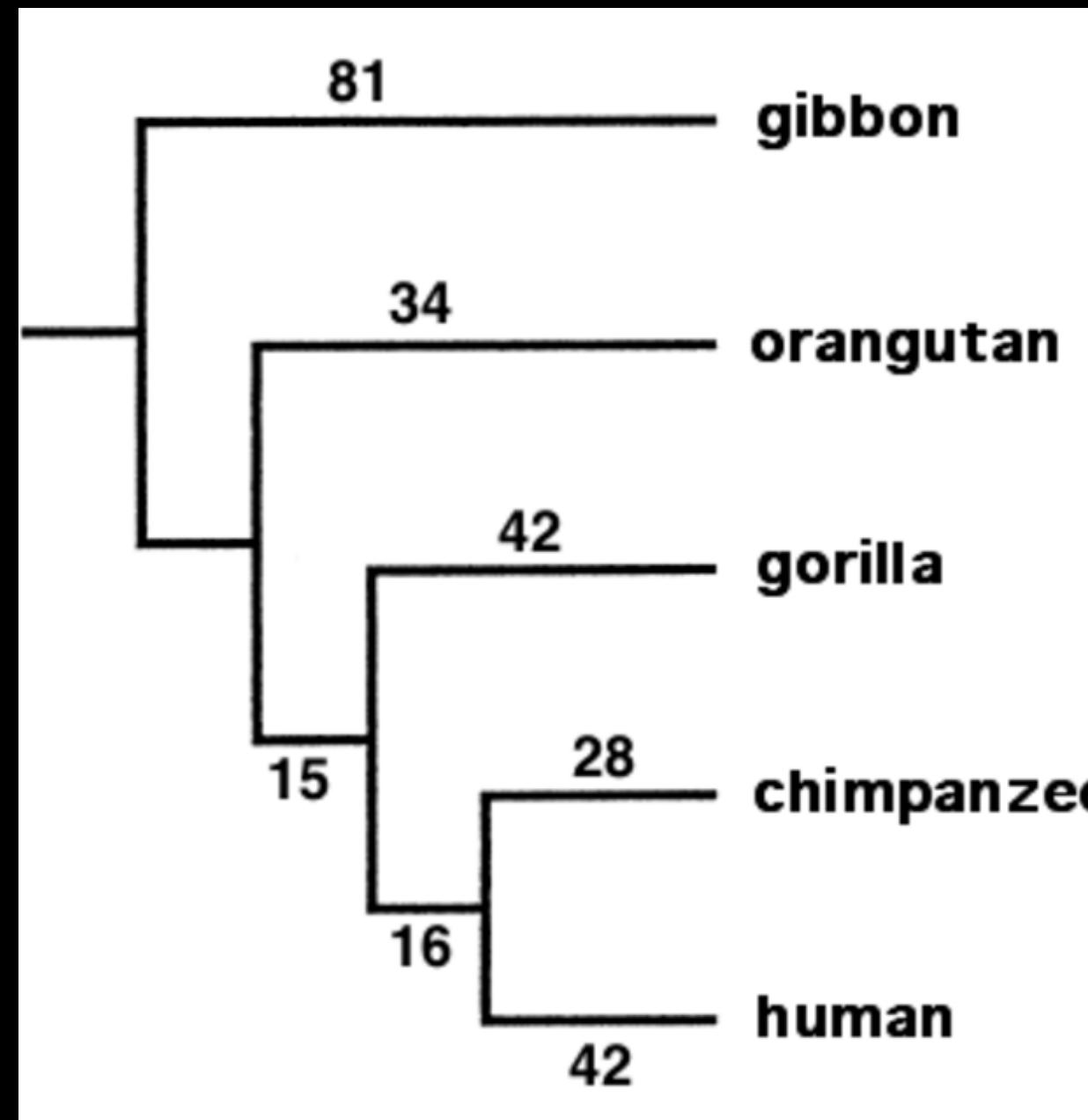


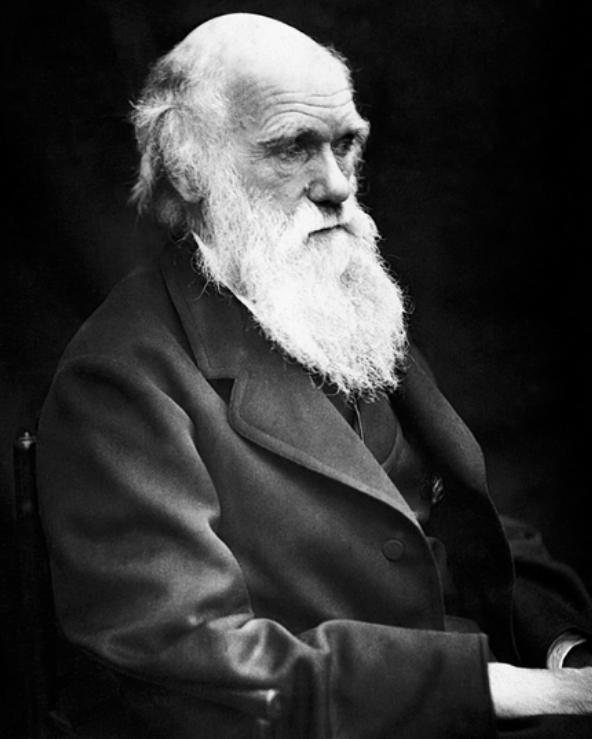
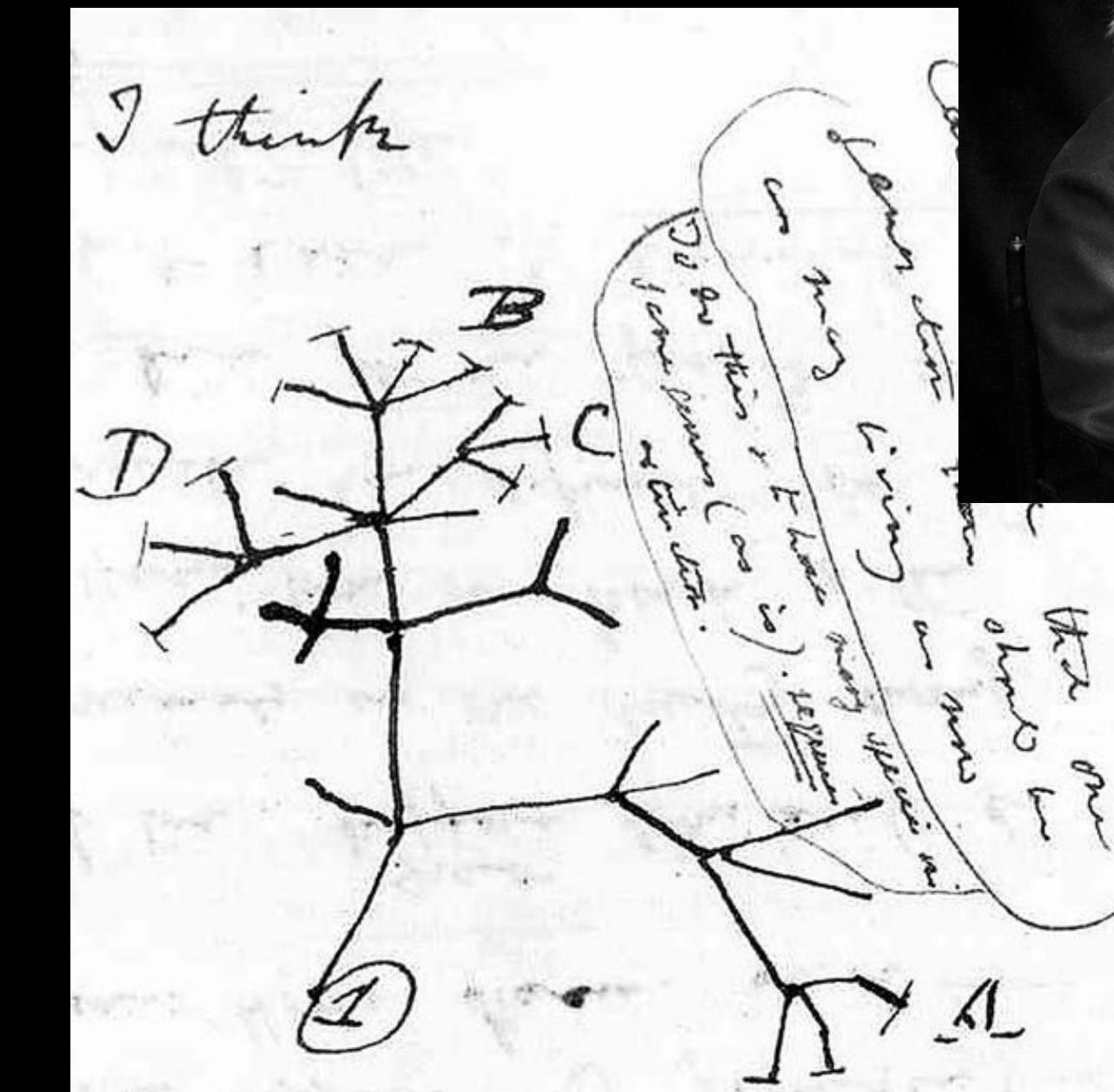
# Tree Thinking

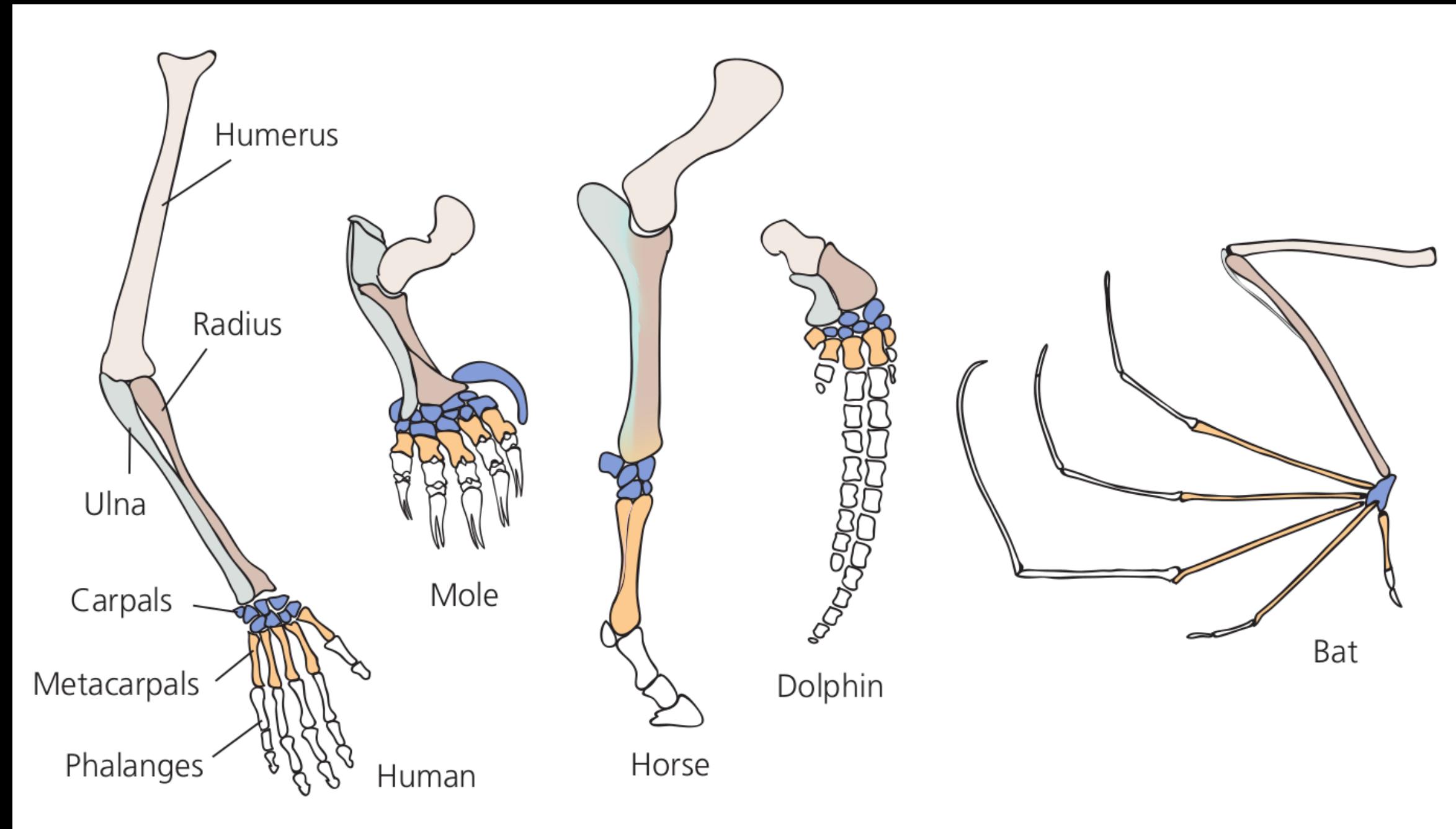
Raphaël Scherrer

# phylogenetic tree

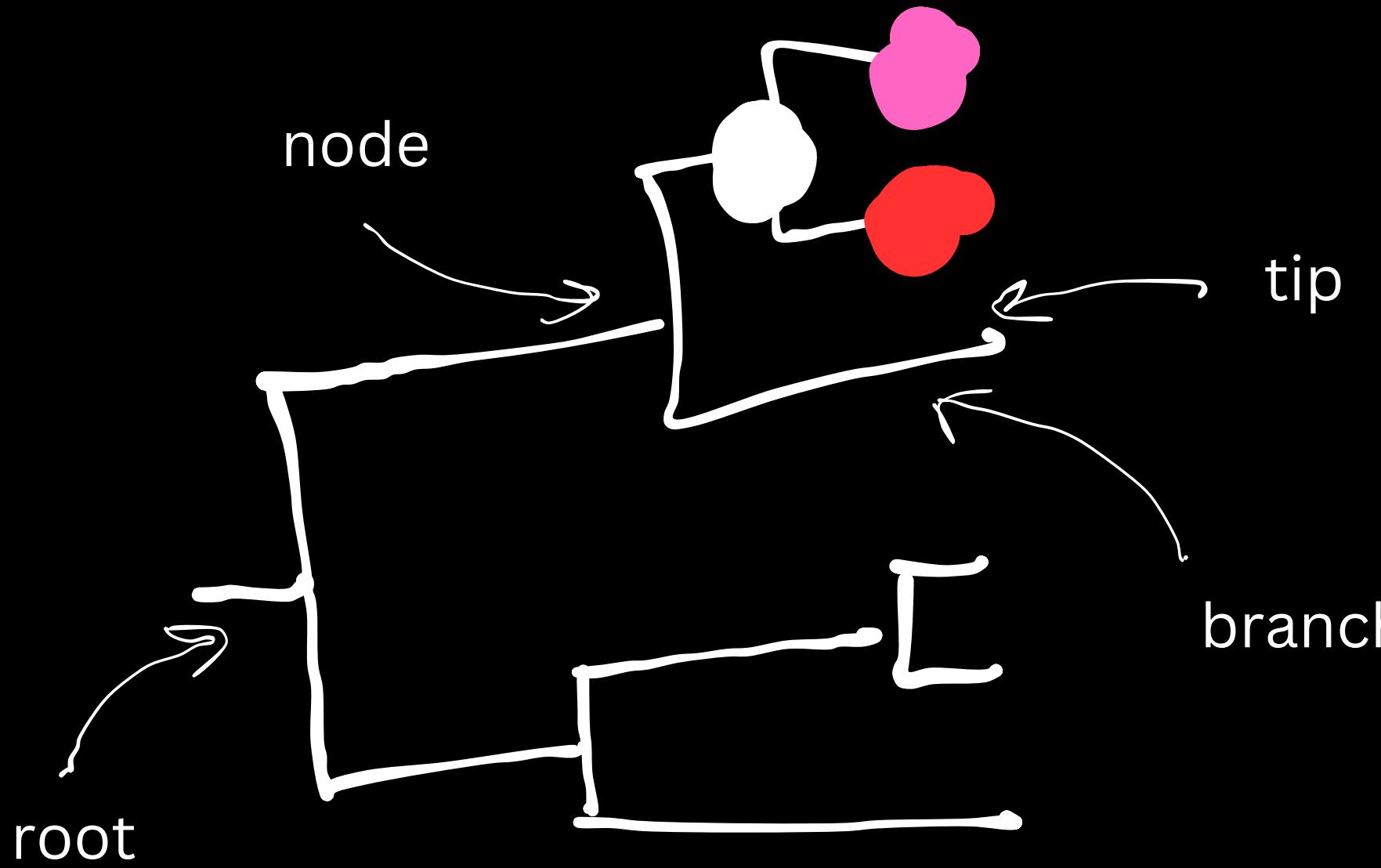


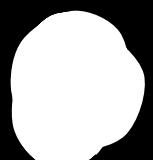
Goldman et al. 1987



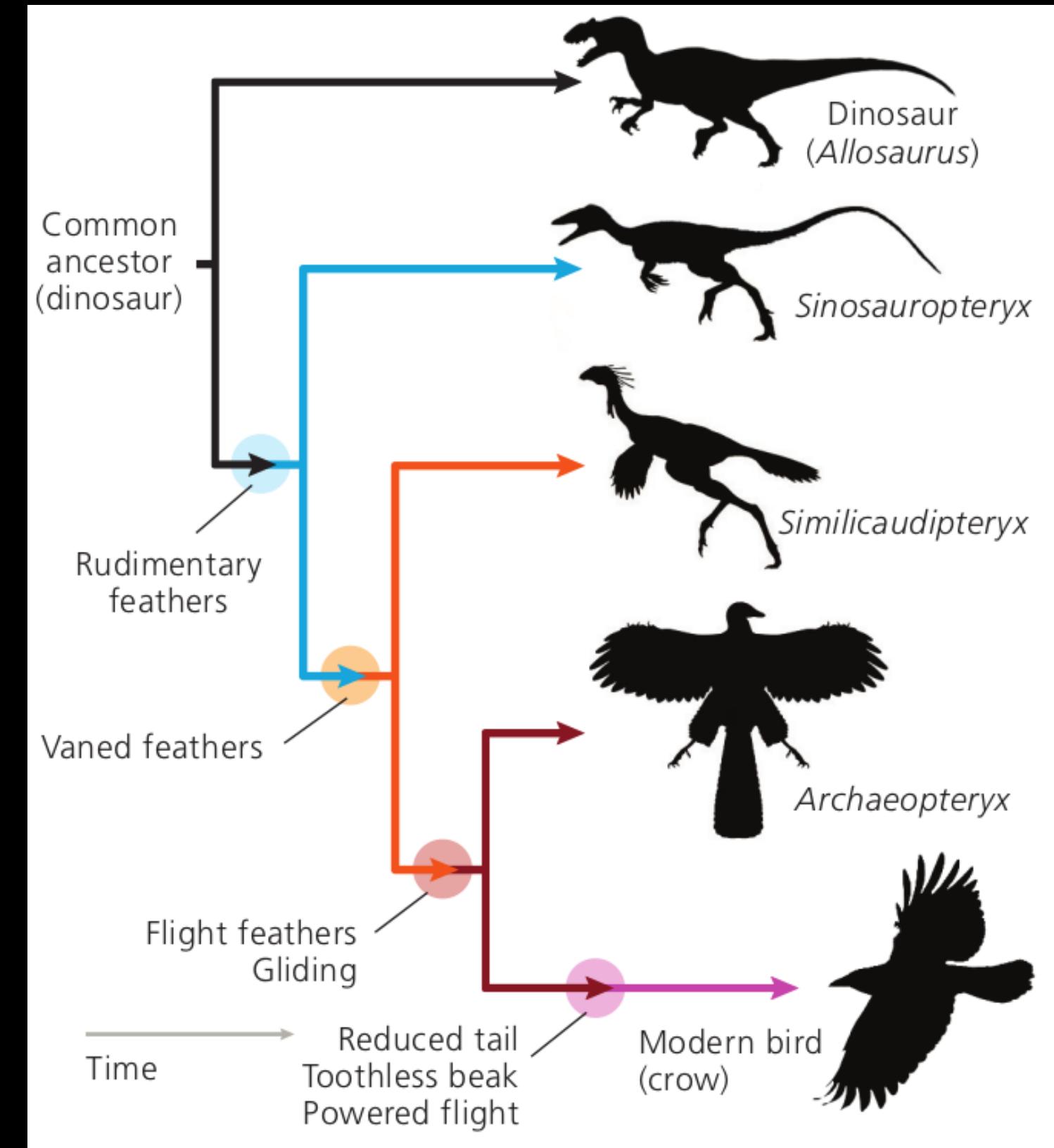


# identity by descent

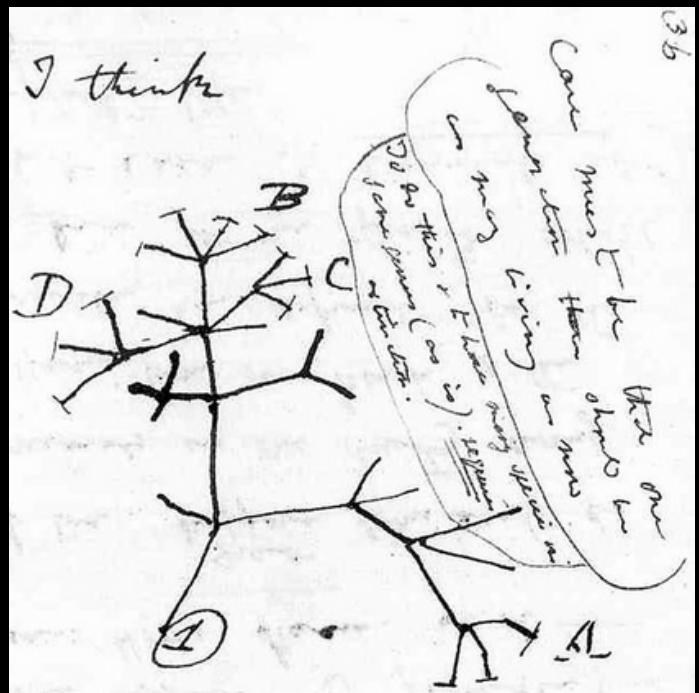


most recent common ancestor  
(MRCA)  
between  and 





# fossils

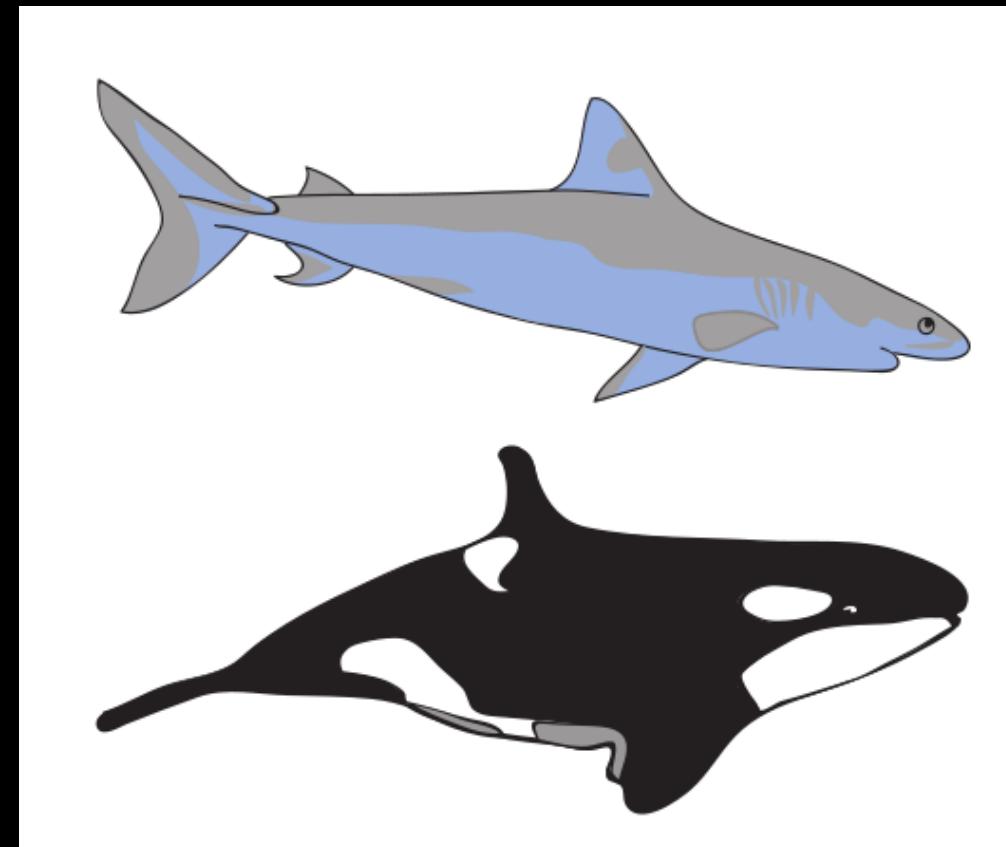
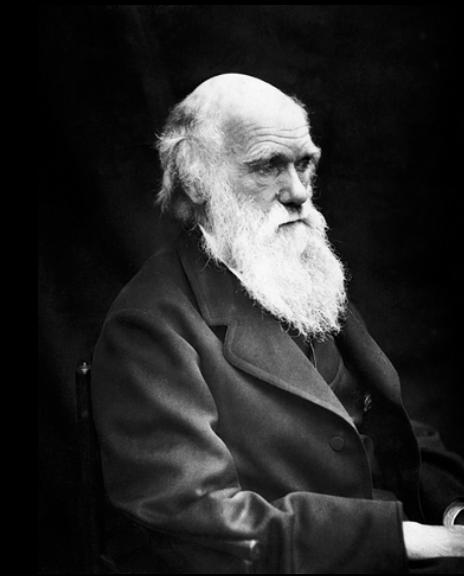


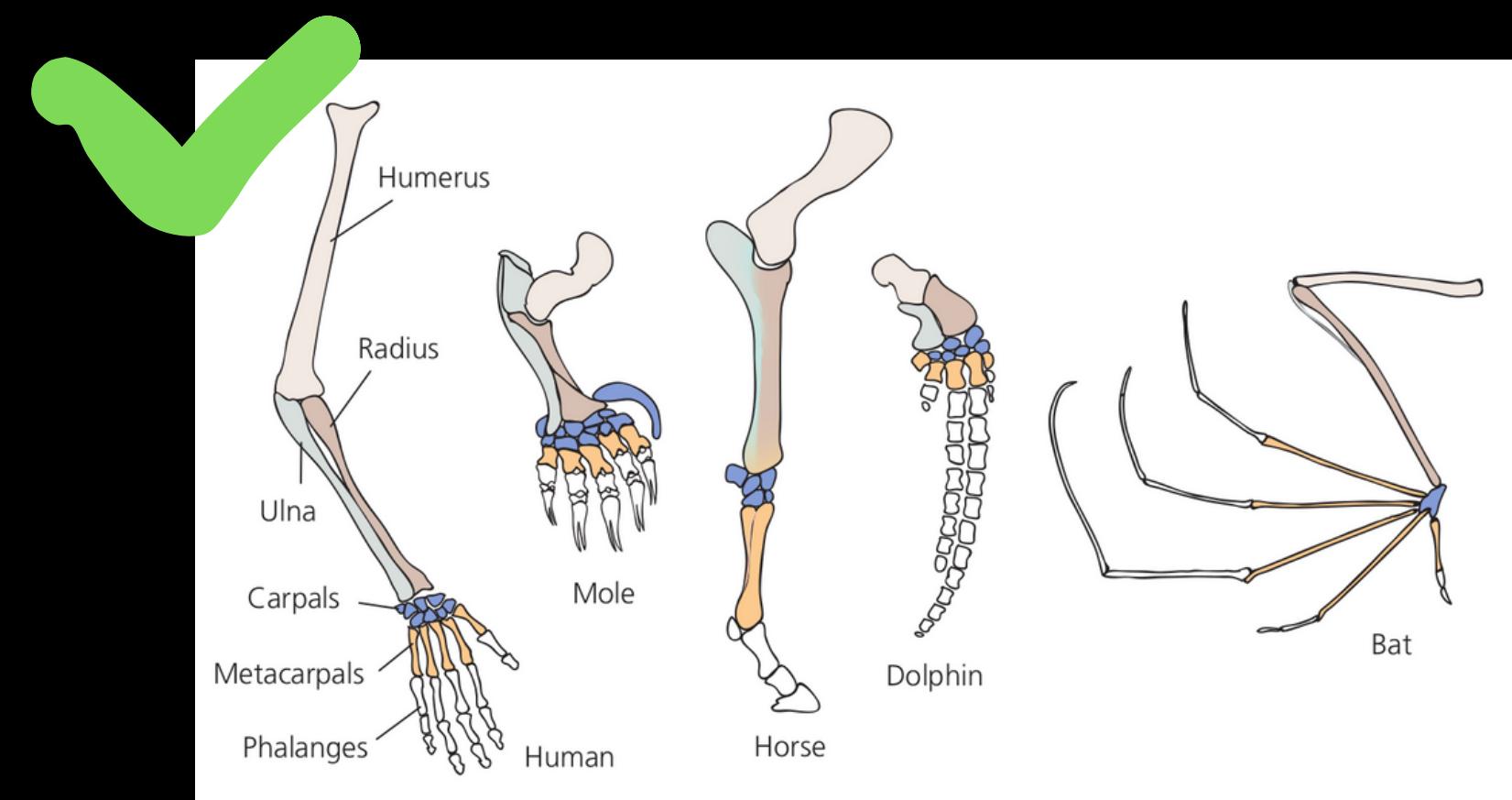
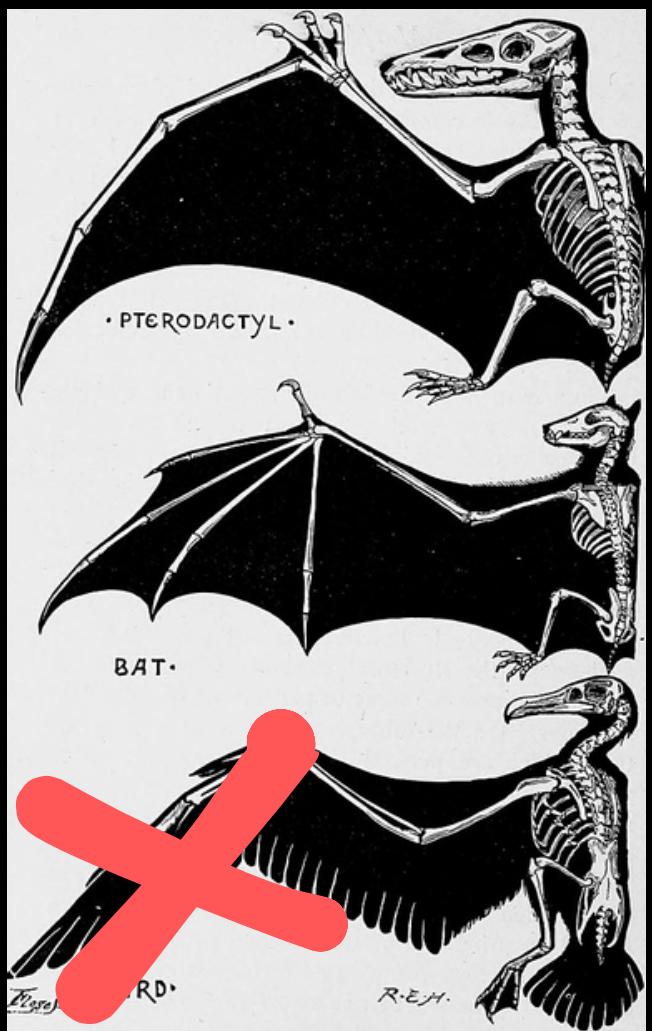
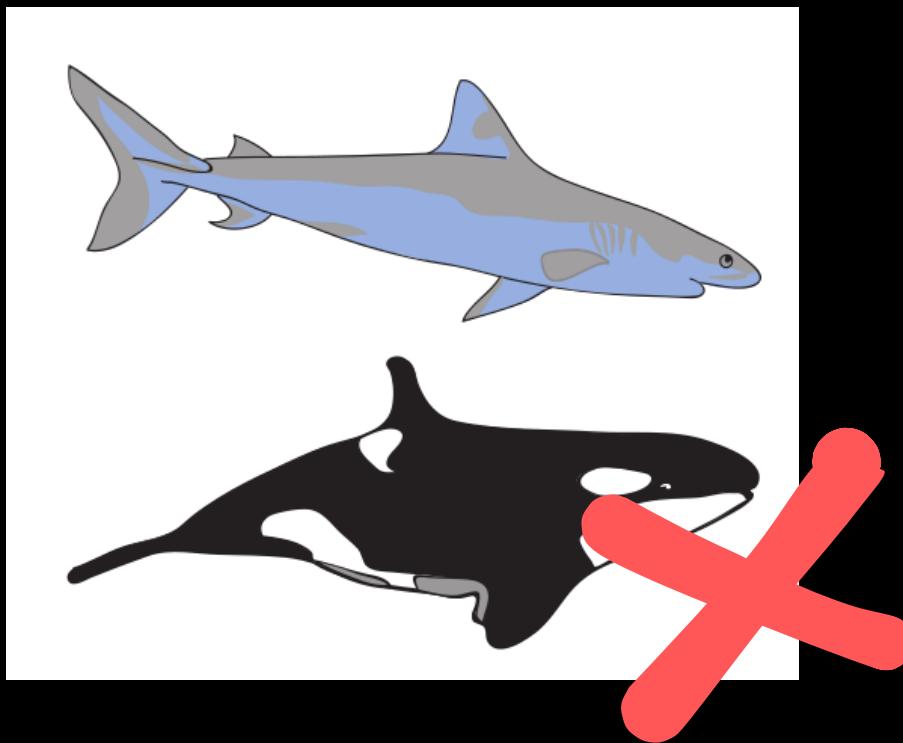
# homologies

identical by descent

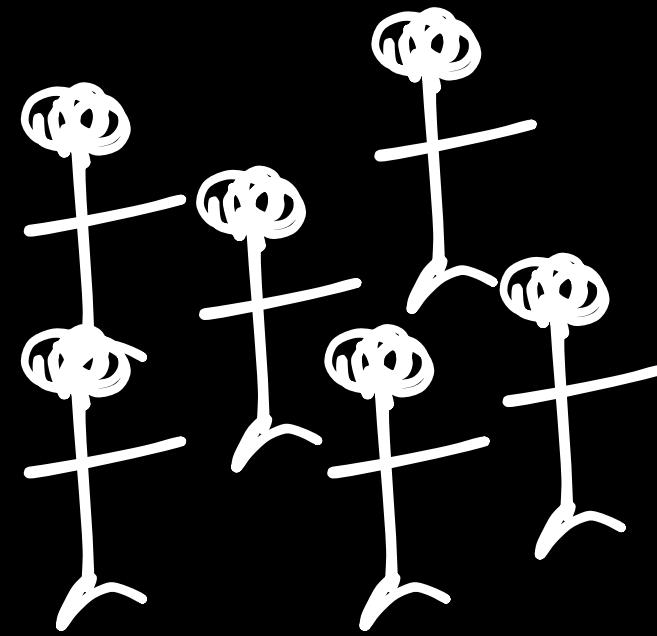


# homoplasies









sequence alignment

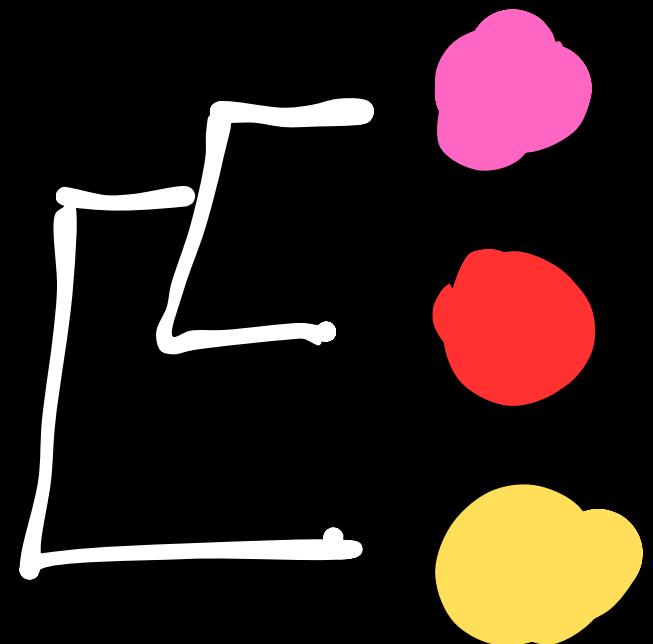


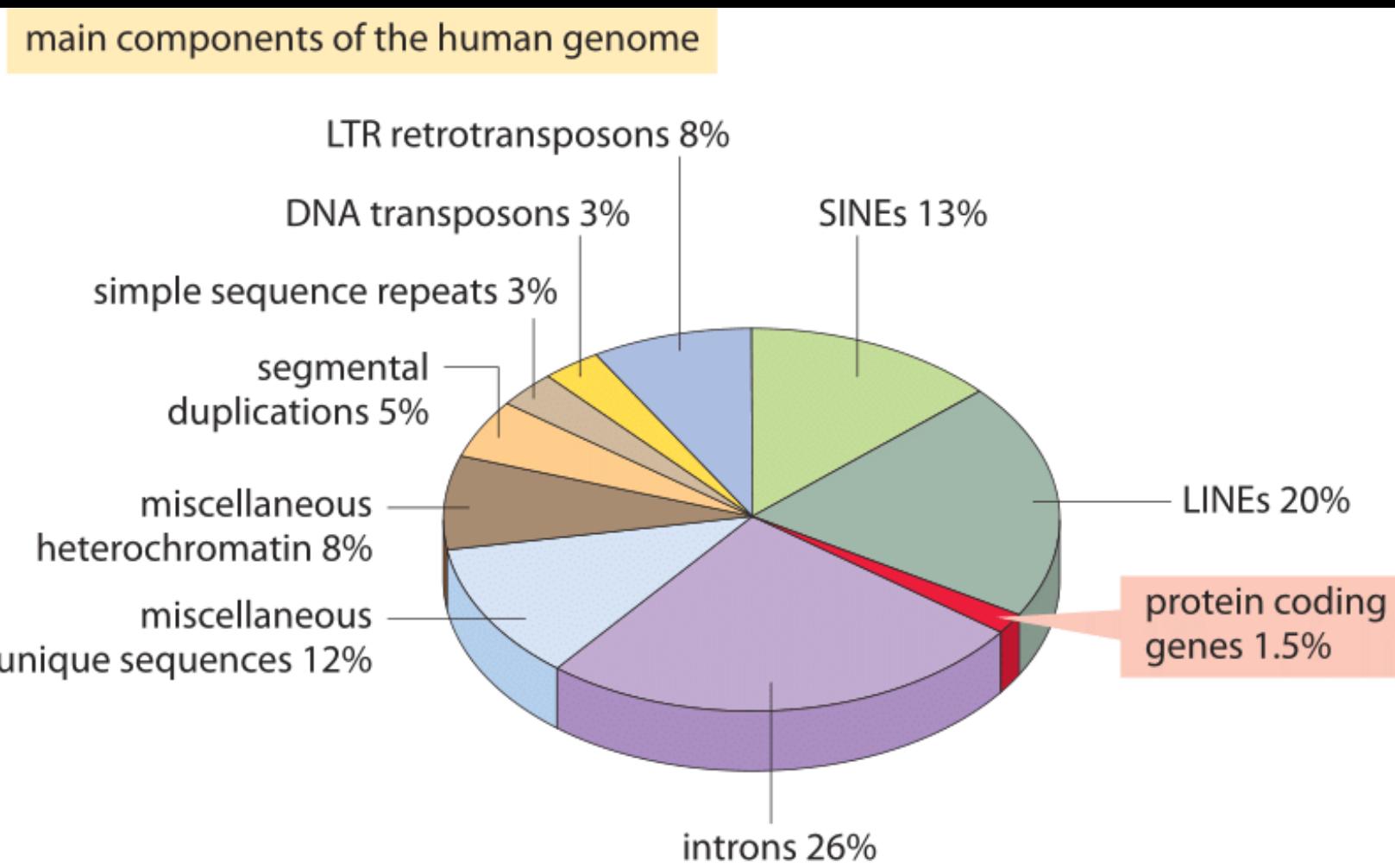
ATTC...TCCGA...GGAA

ATAC...TCCGA...GCAA

ATAC...TCAGA...GCAA

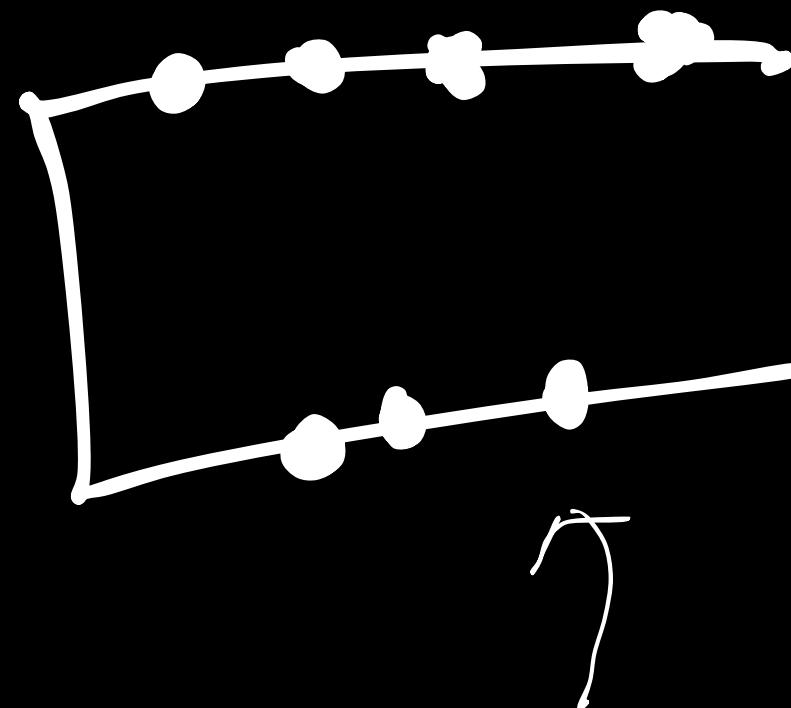
gene trees





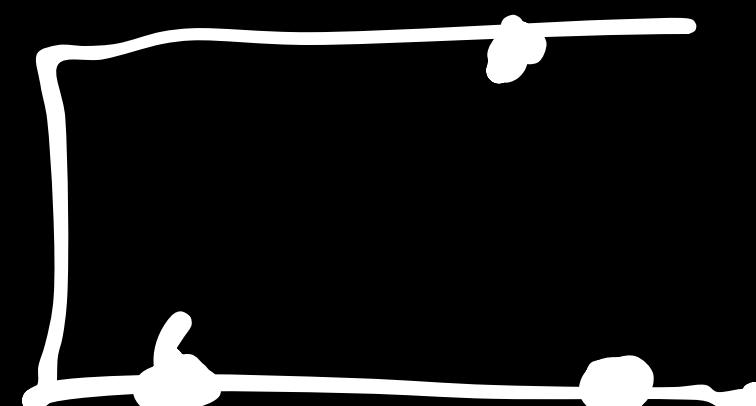
# molecular clock

neutral sequence

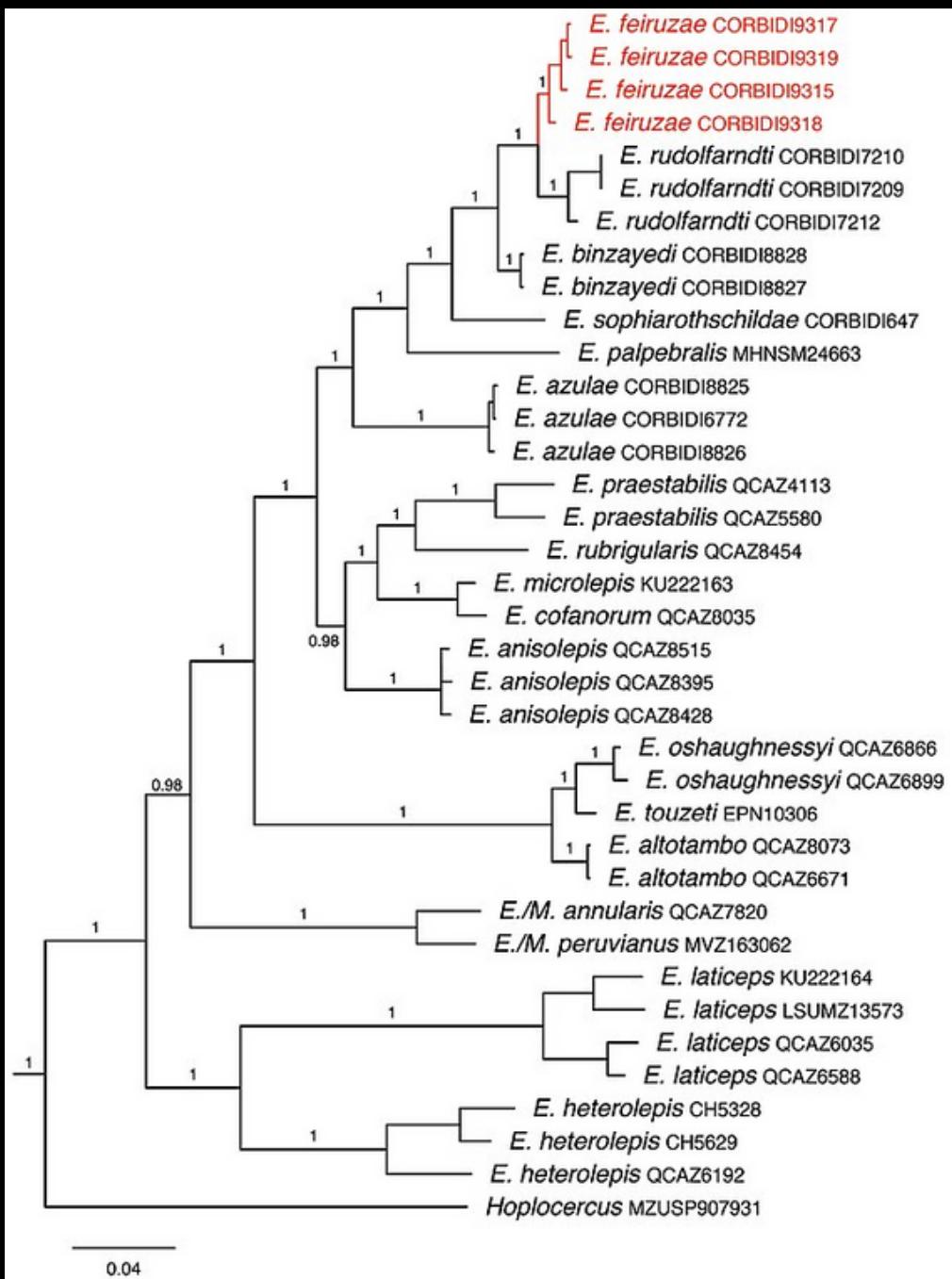


mutation accumulation

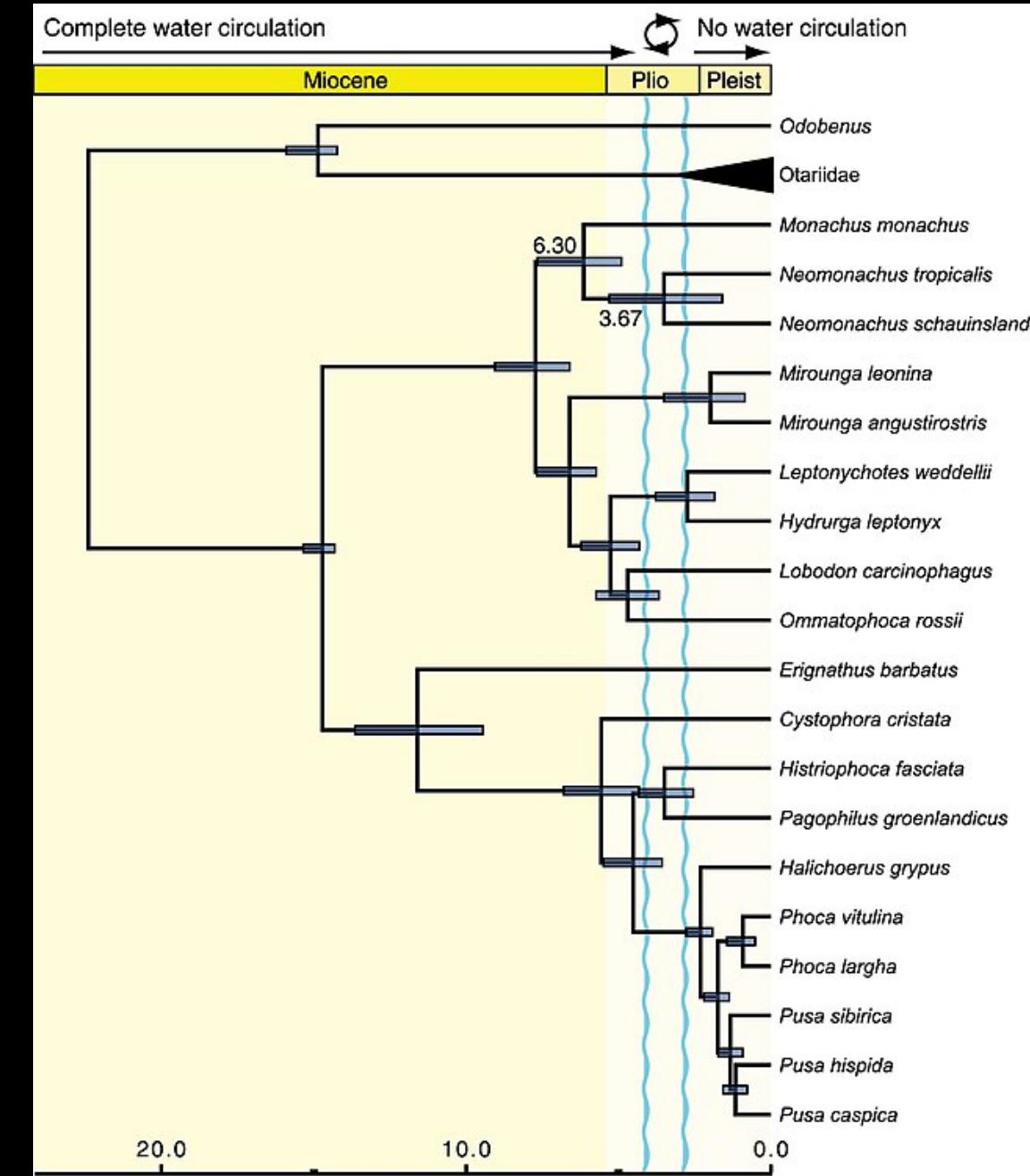
conserved sequence





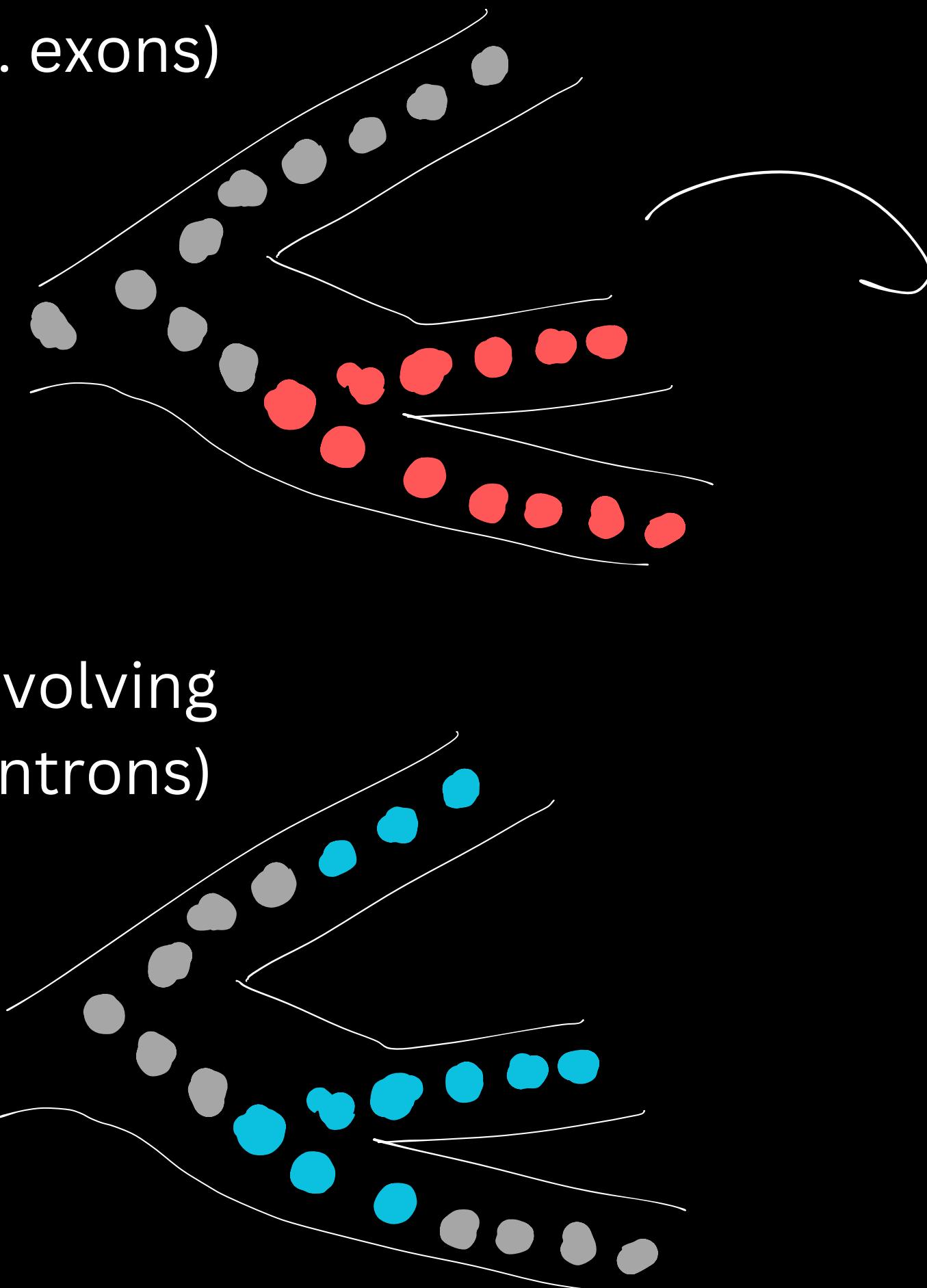


time calibration



ultrametric phylogeny

slow evolving  
(e.g. exons)



### Bacteria

Spirochetes  
Proteobacteria  
Cyanobacteria  
*Planctomyces*  
*Bacteroides*  
*Cytophaga*  
*Thermotoga*  
*Aquifex*

Chloroflexi  
*Methanobacterium*  
*Methanococcus*  
*Thermococcus celer*  
*Thermoproteus Pyrodicticum*

Gram-positives  
Entamoebae  
*Haloarchaea*

Slime molds  
Animals  
Fungi  
Plants  
Ciliates  
Flagellates  
Trichomonads  
Microsporidia  
Diplomonads

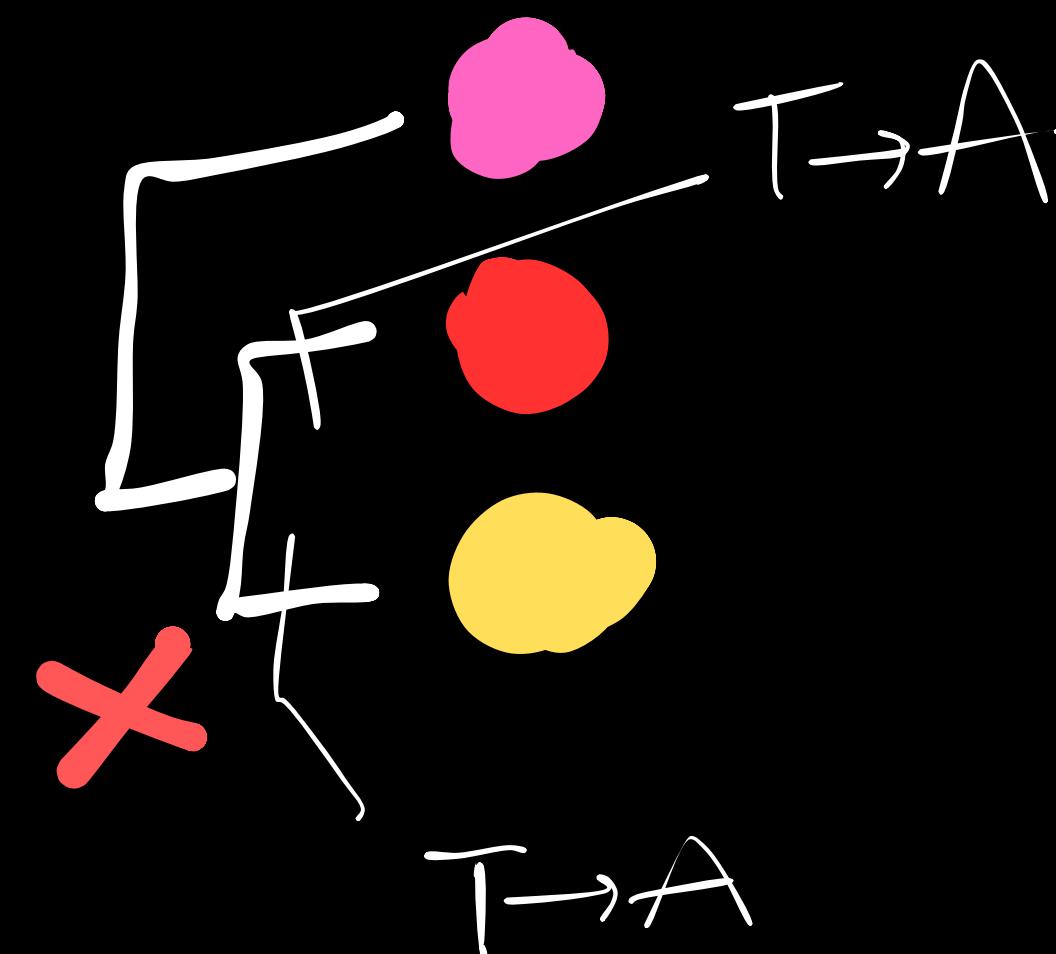
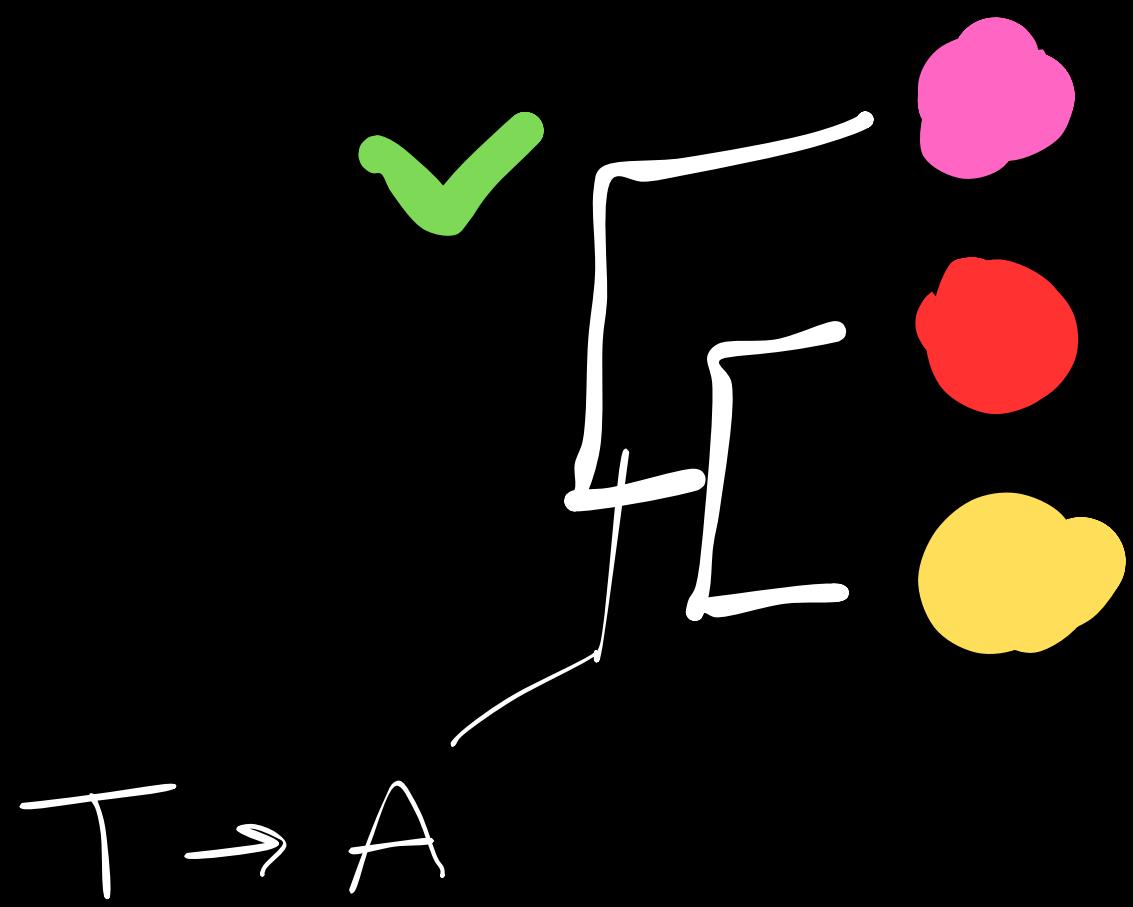
### Archaea

Last Universal Common Ancestor (LUCA)

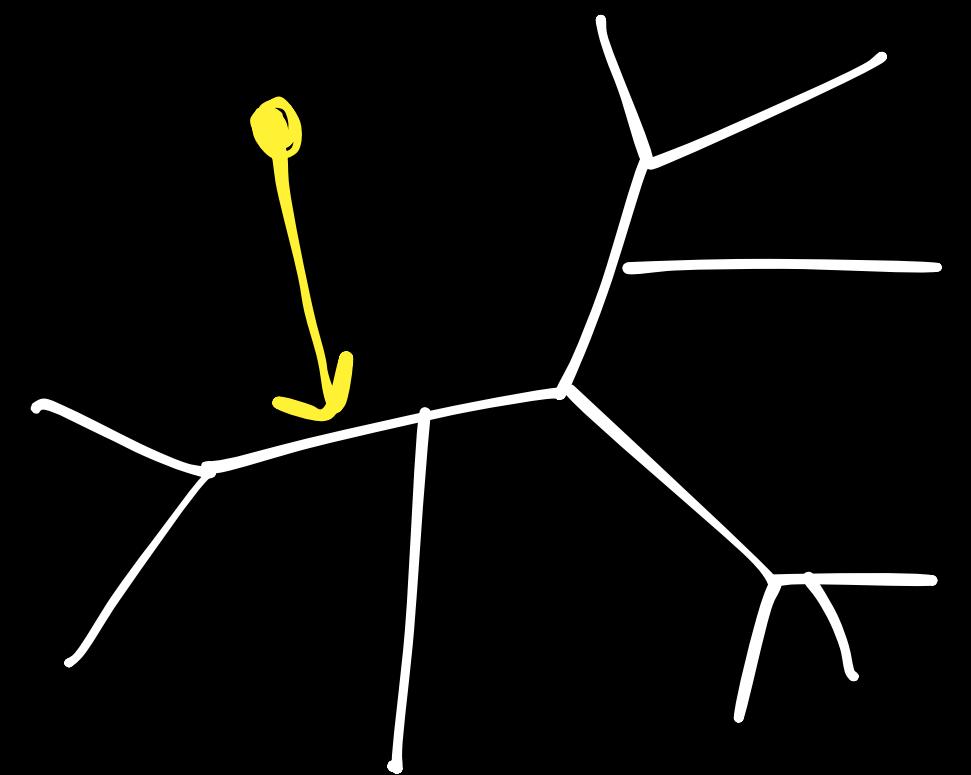
rRNA

### Eukaryota

- ATT...  
ATTC...
- ATAC...  
ATAC...
- ATAC...  
ATAC...

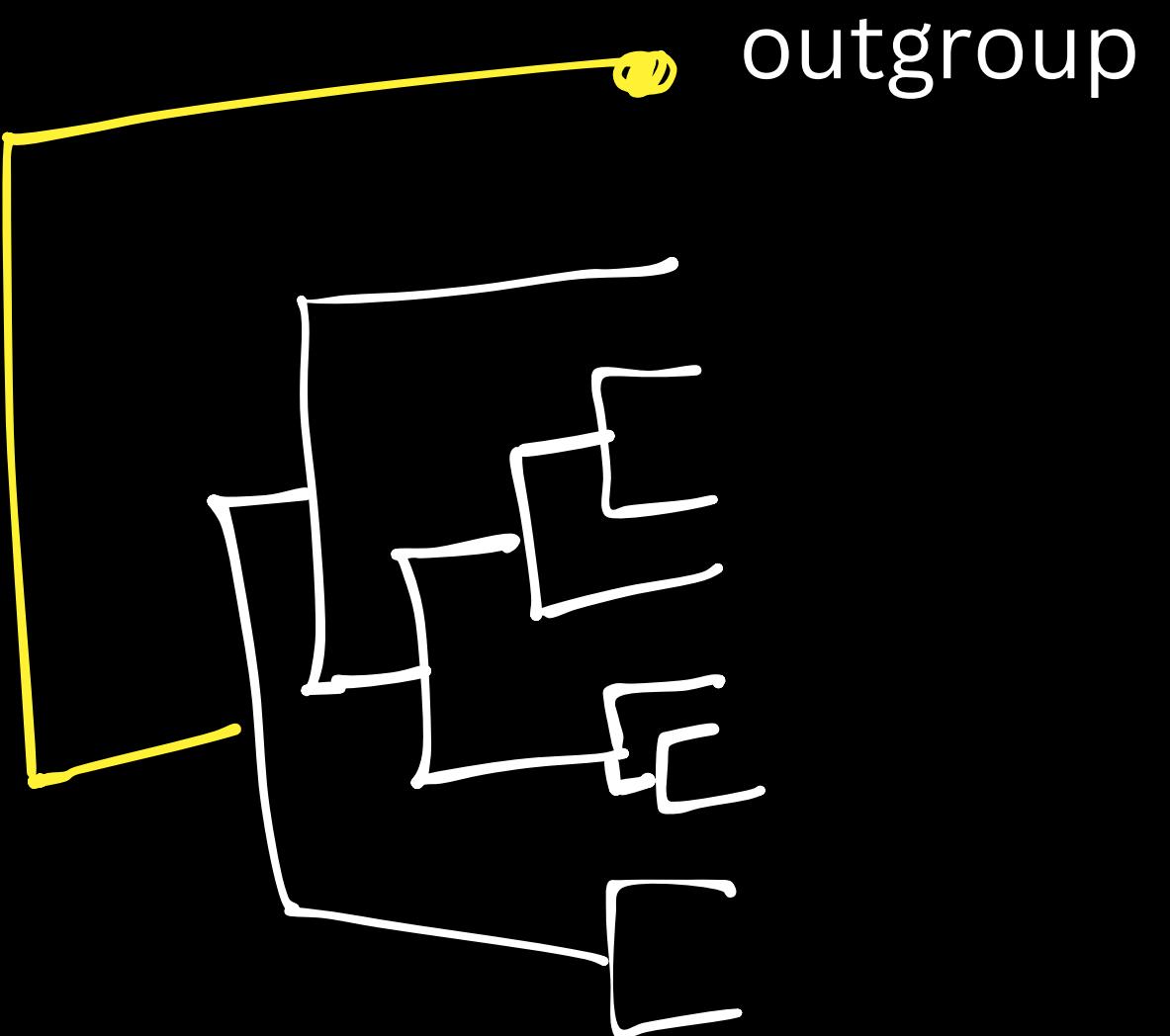


parsimony  
Okham's razor

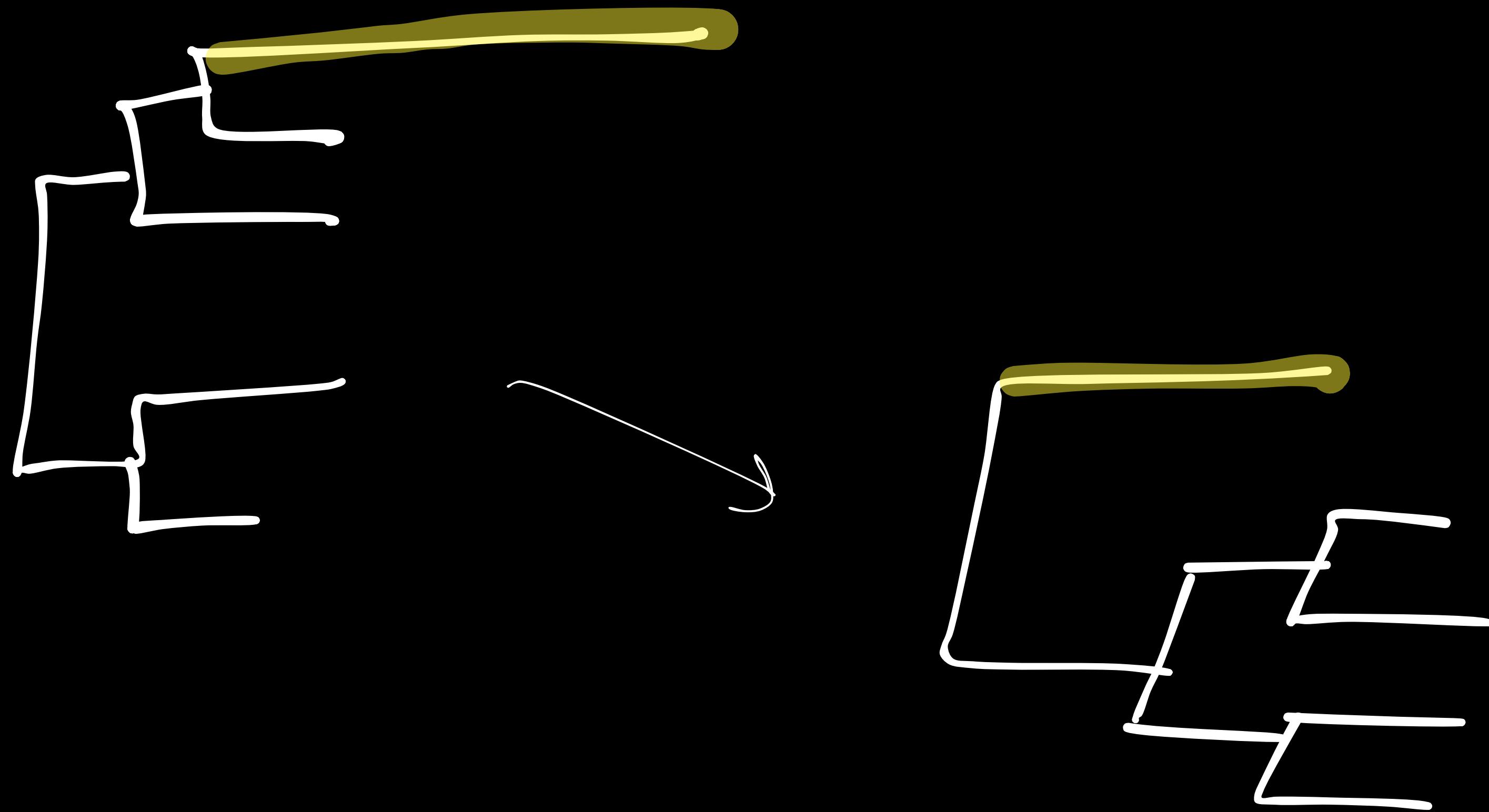


unrooted tree

rooting



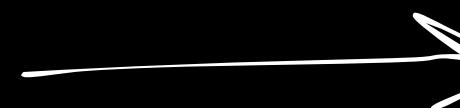
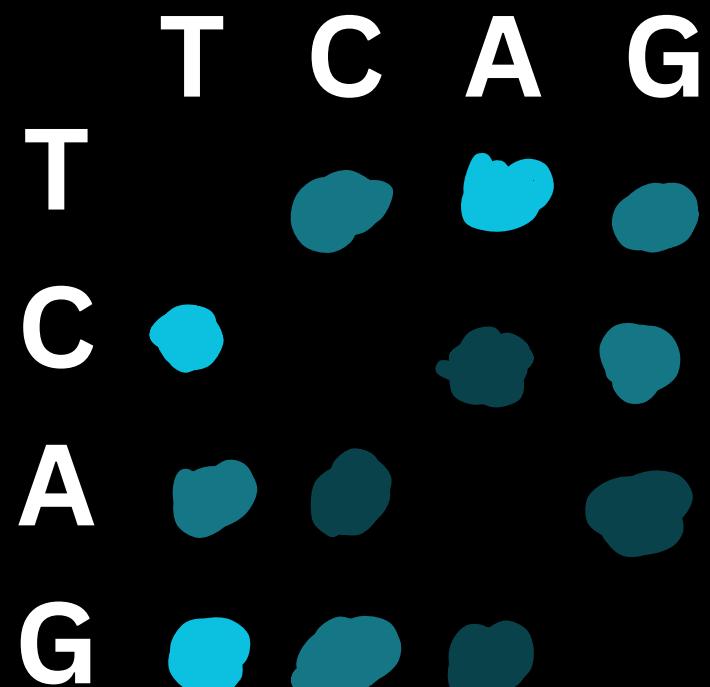
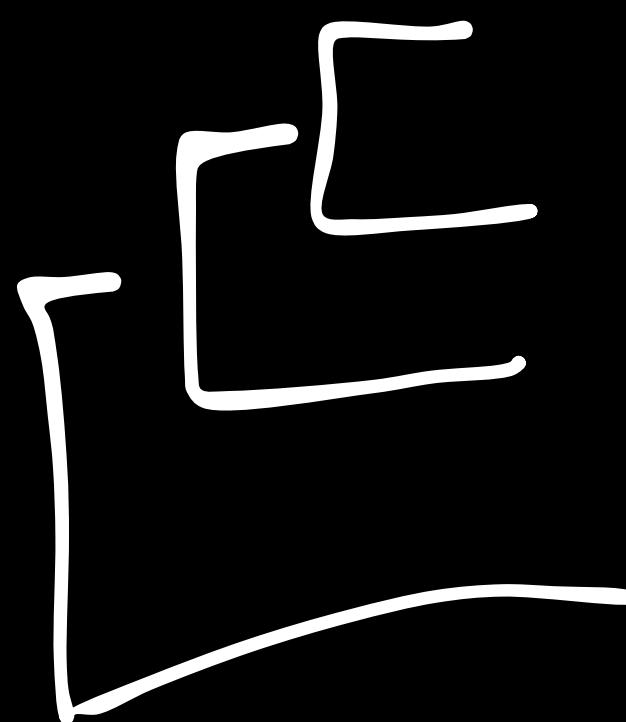
rooted tree



long branch attraction artifact



model

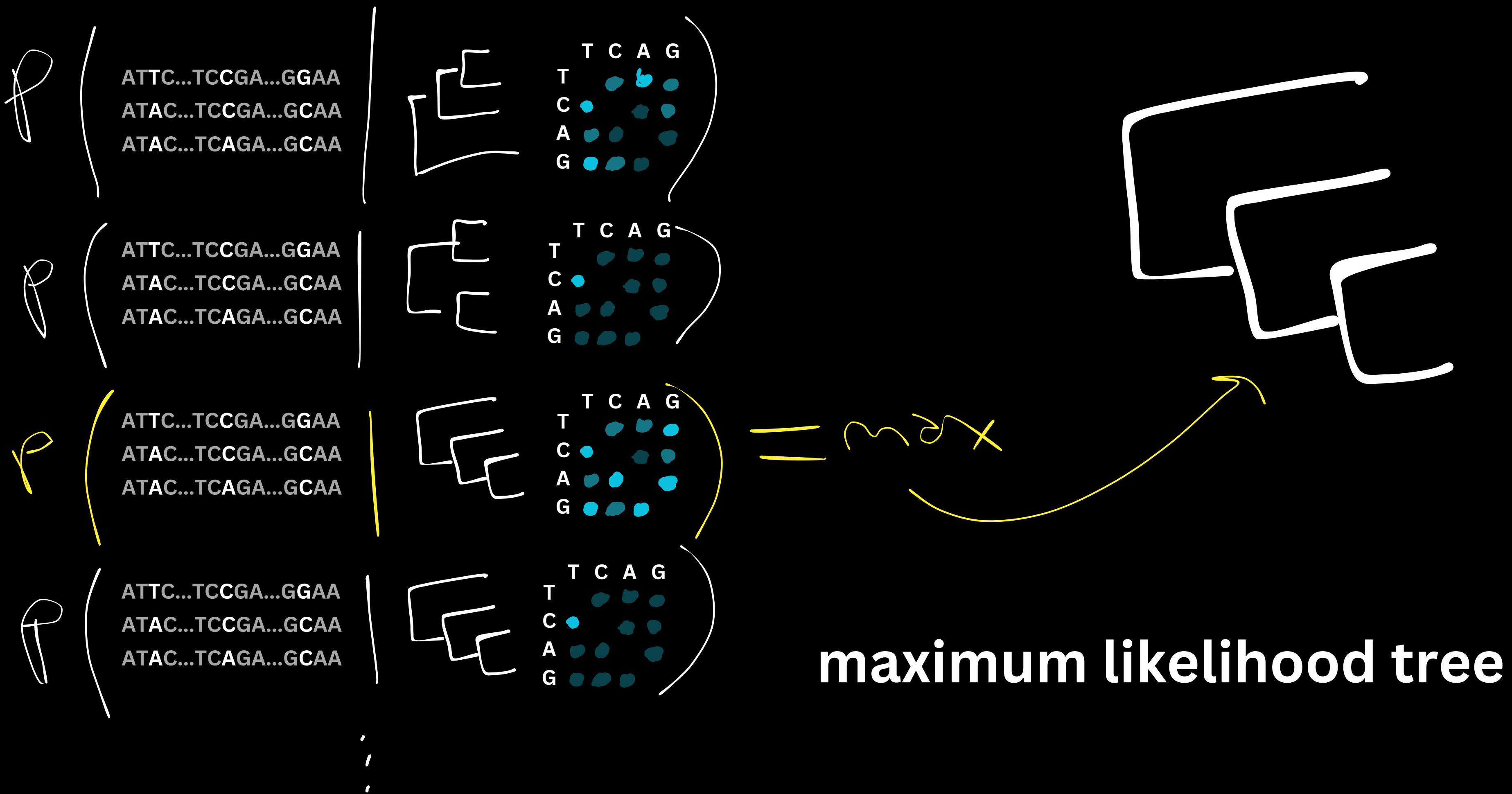


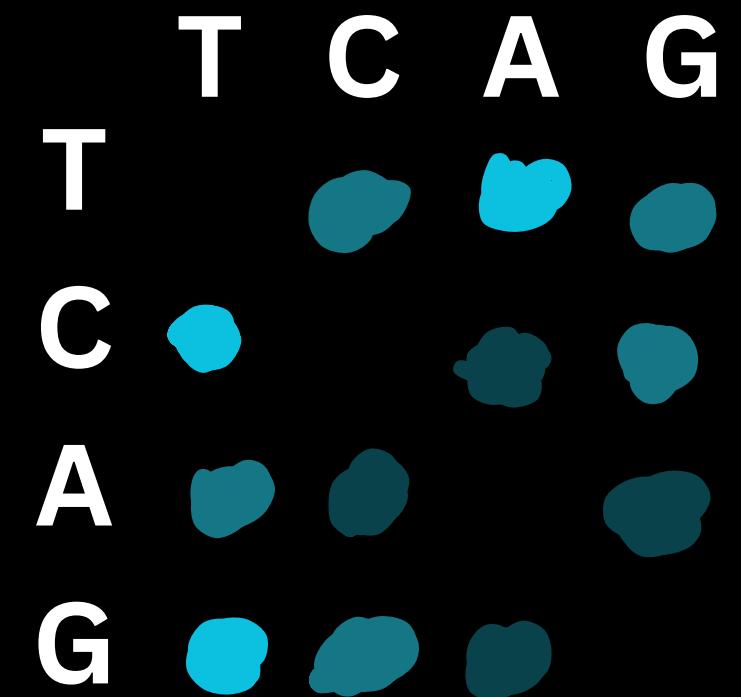
alignment

ATTC...TCCGA...GGAA  
ATAC...TCCGA...GCAA  
ATAC...TCAGA...GCAA

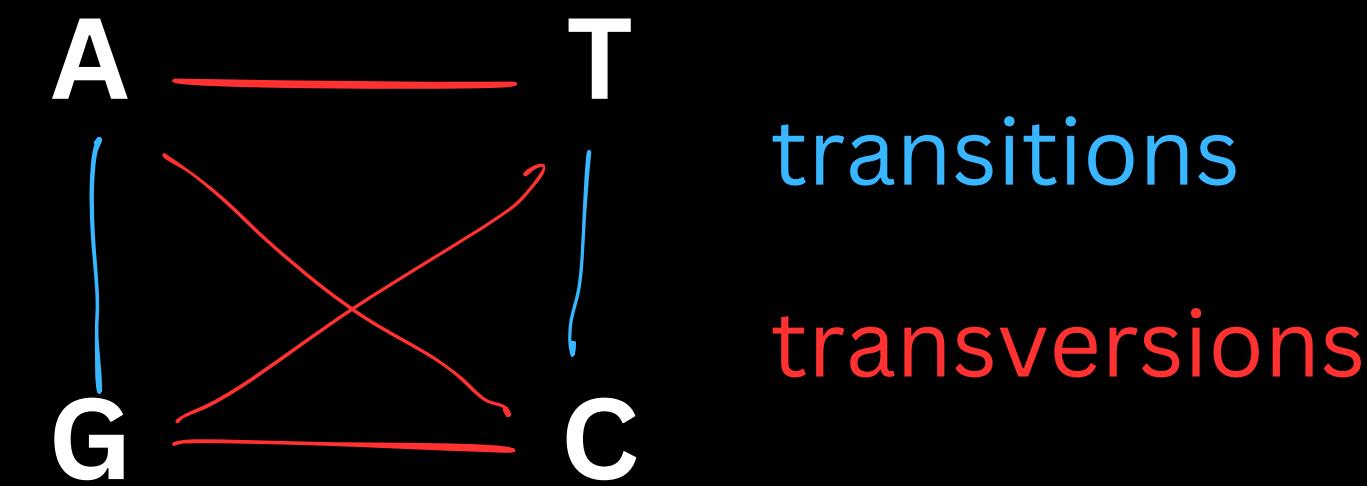


likelihood





constraints e.g. JC69



# Bayesian reconstruction

$$P(\text{tree} | \text{data})$$

posterior probability

ATTC...TCCGA...GGAA  
ATAC...TCCGA...GCAA  
ATAC...TCAGA...GCAA

$$P(\text{tree})$$

prior probability

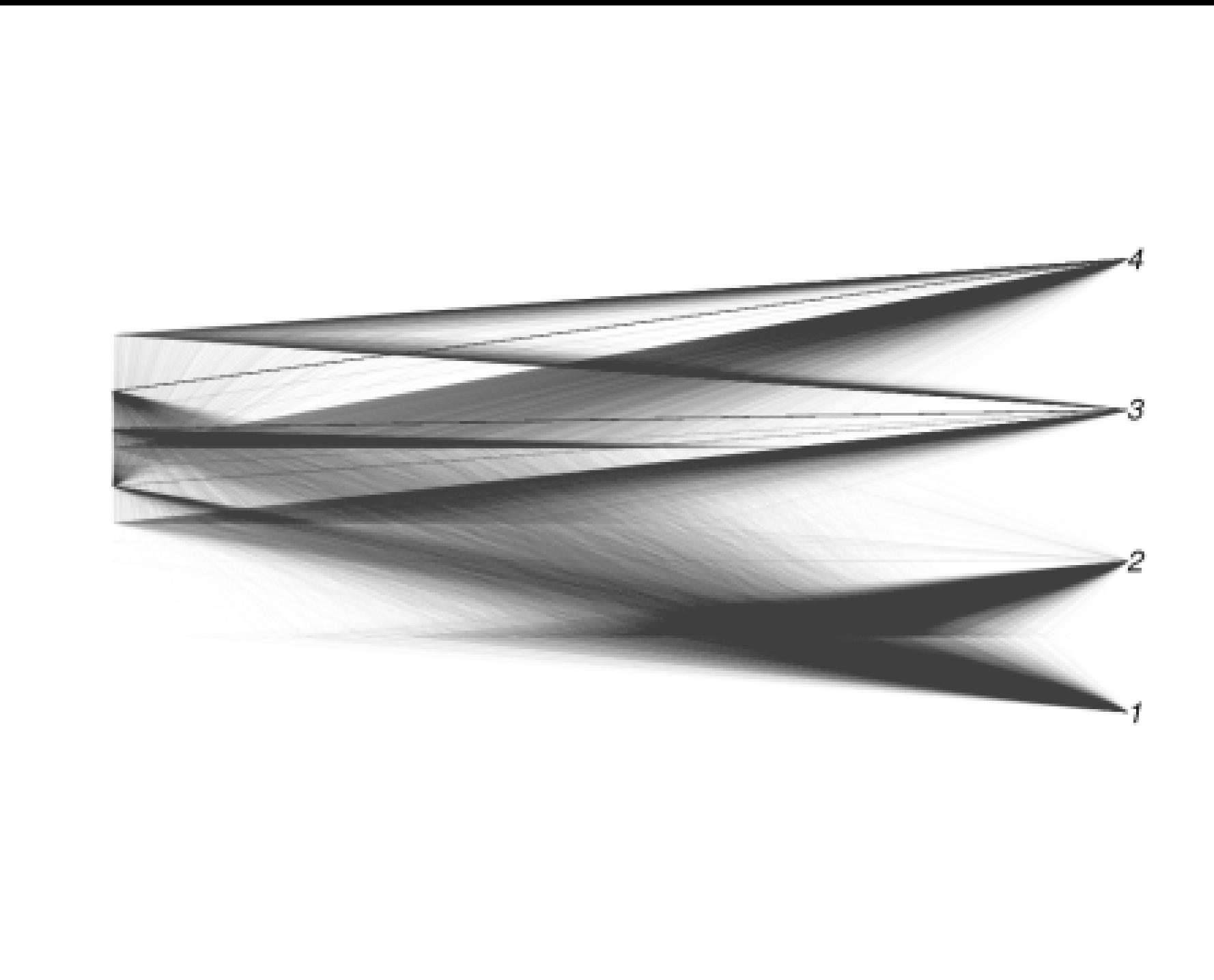
ATTC...TCCGA...GGAA  
ATAC...TCCGA...GCAA  
ATAC...TCAGA...GCAA

$$P(\text{data} | \text{tree})$$

likelihood

$$P(A|\beta) = \frac{P(A) \times P(\beta|A)}{P(\beta)}$$

Bayes' theorem



credit: Richel Bilderbeek

# phylogenomics

tcaaagttagataaacatgatcattcacaggtcagatgtttaaaaaaaaatcattatggtgtacatcacatgttagacaataacttcagaattcatc  
tggactaccagaatttagttaccttagtacttctcaattctatttaccctaaccgtctaataaataacaaggtaactcttagcctcttcgtttatgattccctc  
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**TCTTTCTTCATCGTCTTCCAACCTTCACGTTCCACCTTATTGTTCAGgttcgtcttagttgcttacatacacagactctacacac**  
tcacttattgggtttcttcaattgtgaaacag**AGTTCAATTGGGAGTCATGGAAGAAAGAAGGAGGATTCTACAATTCTCCACAACCTCCATTGACG**  
**ACATAGCCAACGCTGGAATCACTCATTTGGCTTCCTCCTCTCAATCCGTTGCTCCTGAAGGgttccattctgcttactcttacacattcaca**  
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CTGTTATTCGAAGGTGGACTTCCGATGATCGTCTTGATTGGGATCCTTCTTGTCTGCCGCAATGACCTAAATTCCCGTACCGGAAACCTCGAC  
ACCGGAGGGAGATTTGATGGAGCGCCCGACATCGAC**CCTTAACCTTCACCTTACGTTGTCGAATGGATGAATTGGCTTAAACTGAAATCG**  
**GATTCCATGGTTGGAGATTGATTATGTTGAGGTTAAGCATCTTCACCATGATTCAGgtaaatcacatatacgatattctcaaataatcagac**  
aacagtatttagtatataagaaacataggttagataattttactatttagtatataagatcataggtgatagggttatttactactatttagtat  
ataagaaacataagtcaatgcaatcaataagaaatataagaaatgttcaactactgattatgtgataaaattcctctgtttggatacacag**AATACATC**  
**ACCGGATTTCGGTGGGTGAGAAATGGGACGATATGAAGTACGGAGGAGACGGAAACTAGACTATGATCAGAACGAGCATCGGTCGGTCTCAAACAG**  
**TGGATCGAGGAAGCGGGTGGTGTGTTGACAGCTTGTGATTCACCAACCAAGGGATCTTACAGTCTGCTGTCAGGTGAGCTTGGAGACTAAAGG**  
**ACTCGCAGGGAAAACCGCCTGGTATGATAGGAATCATGCCCGAACGCTGTCACATTGATAACCAGATAACATTGAGATACATTGAGAACGTGGTTCCCTTC**  
**TGATAAAAGTCTGGATACGTTATATACTCATCCAGGAACCTGCATTgtaaatgtatgtatgtactattacaactac**  
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# applications