
Lecture 1.1

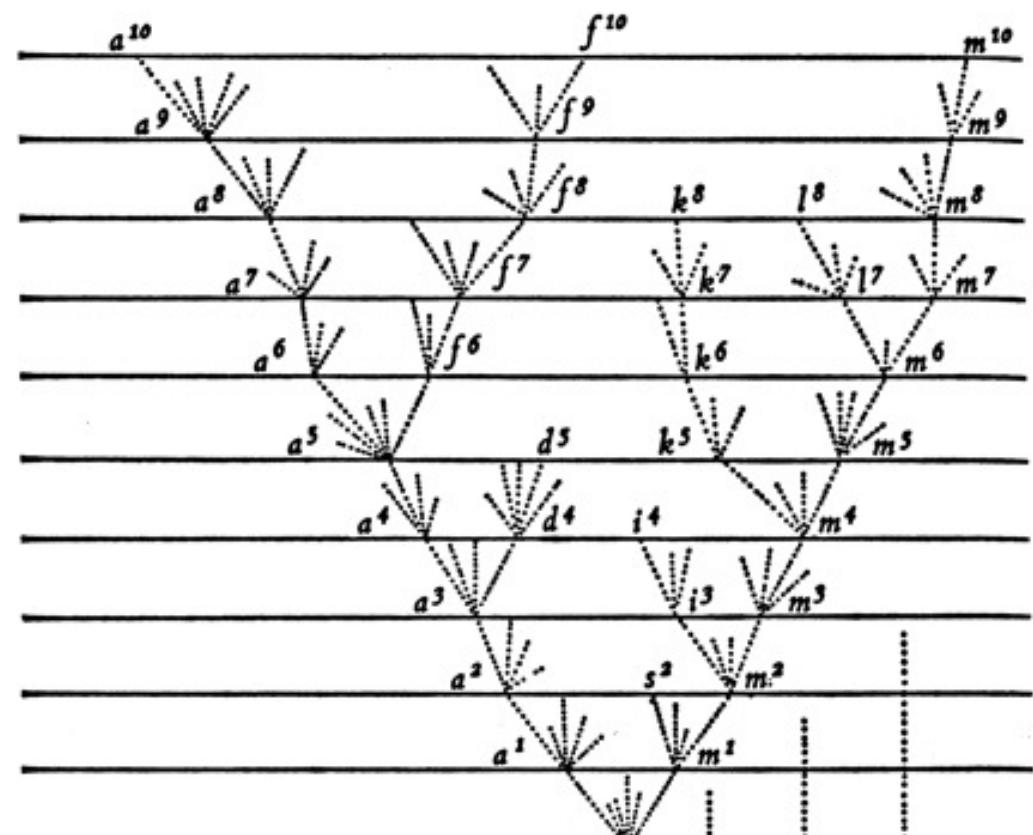
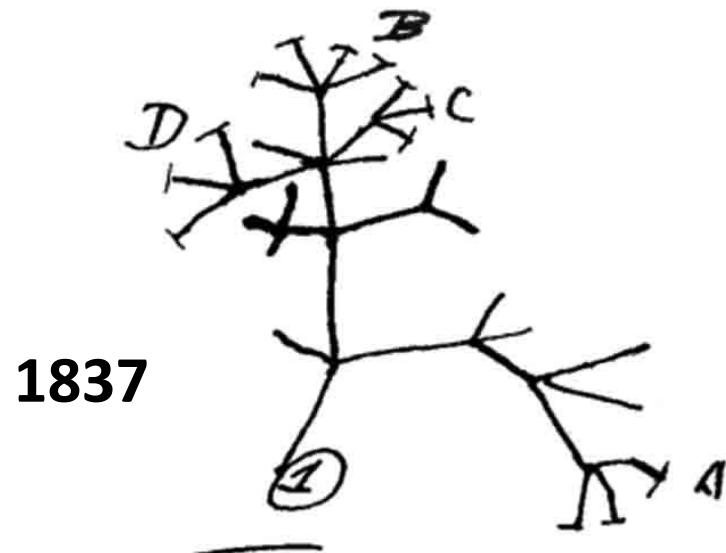
Introduction to Molecular Phylogenetics

Phylogenetic Trees

What is a phylogenetic tree?

Phylogeny
evolutionary relationships
among a set of organisms

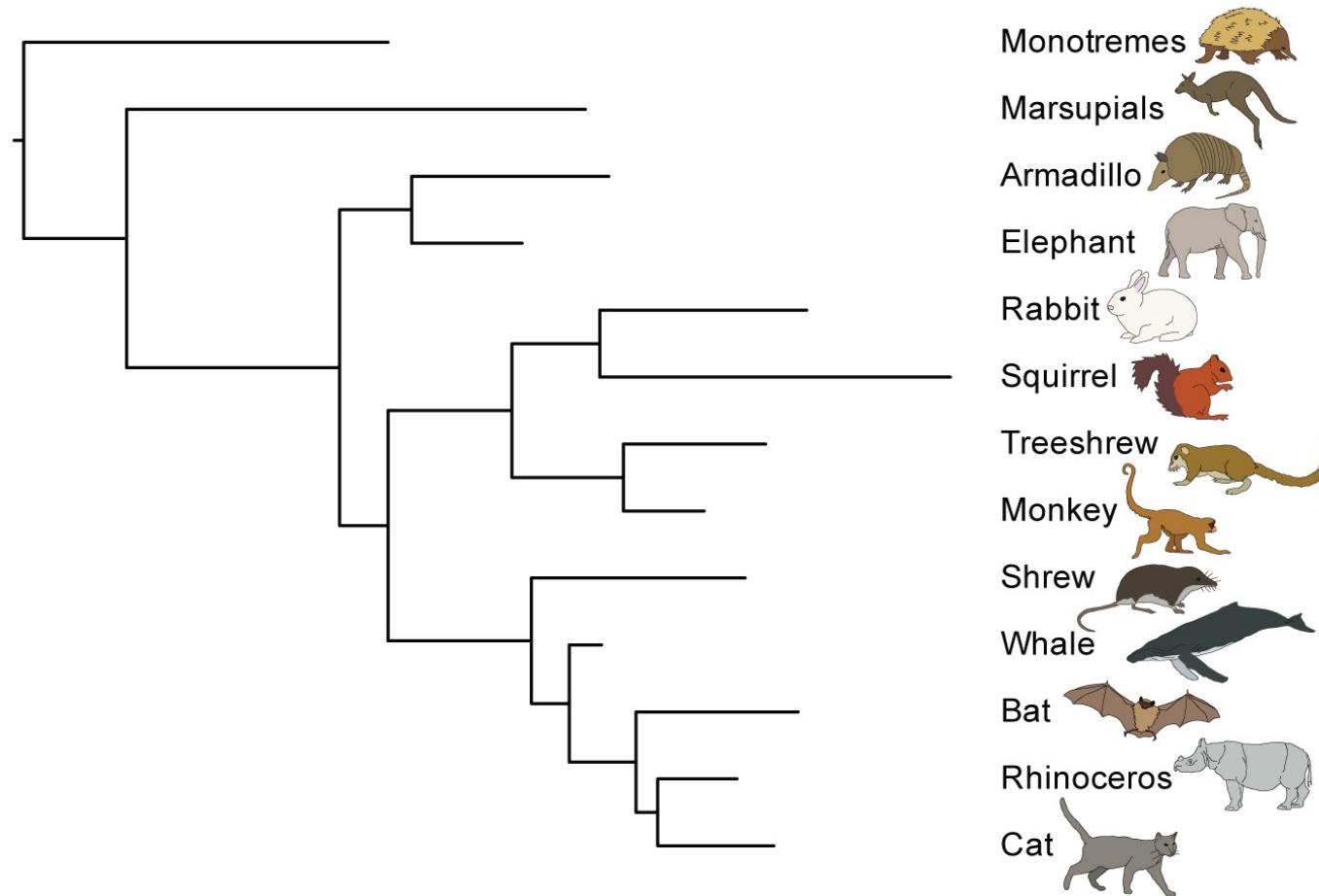
I think

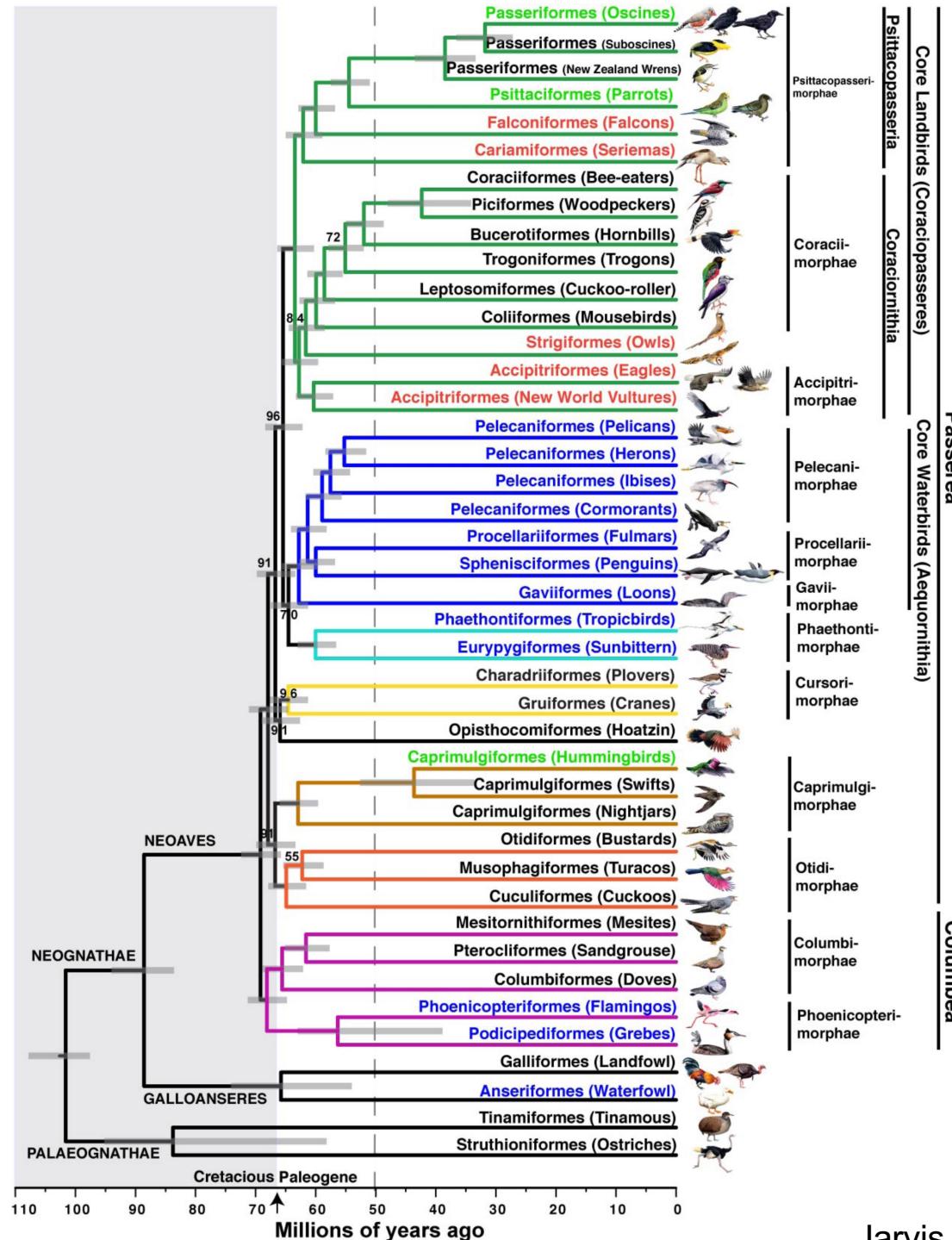


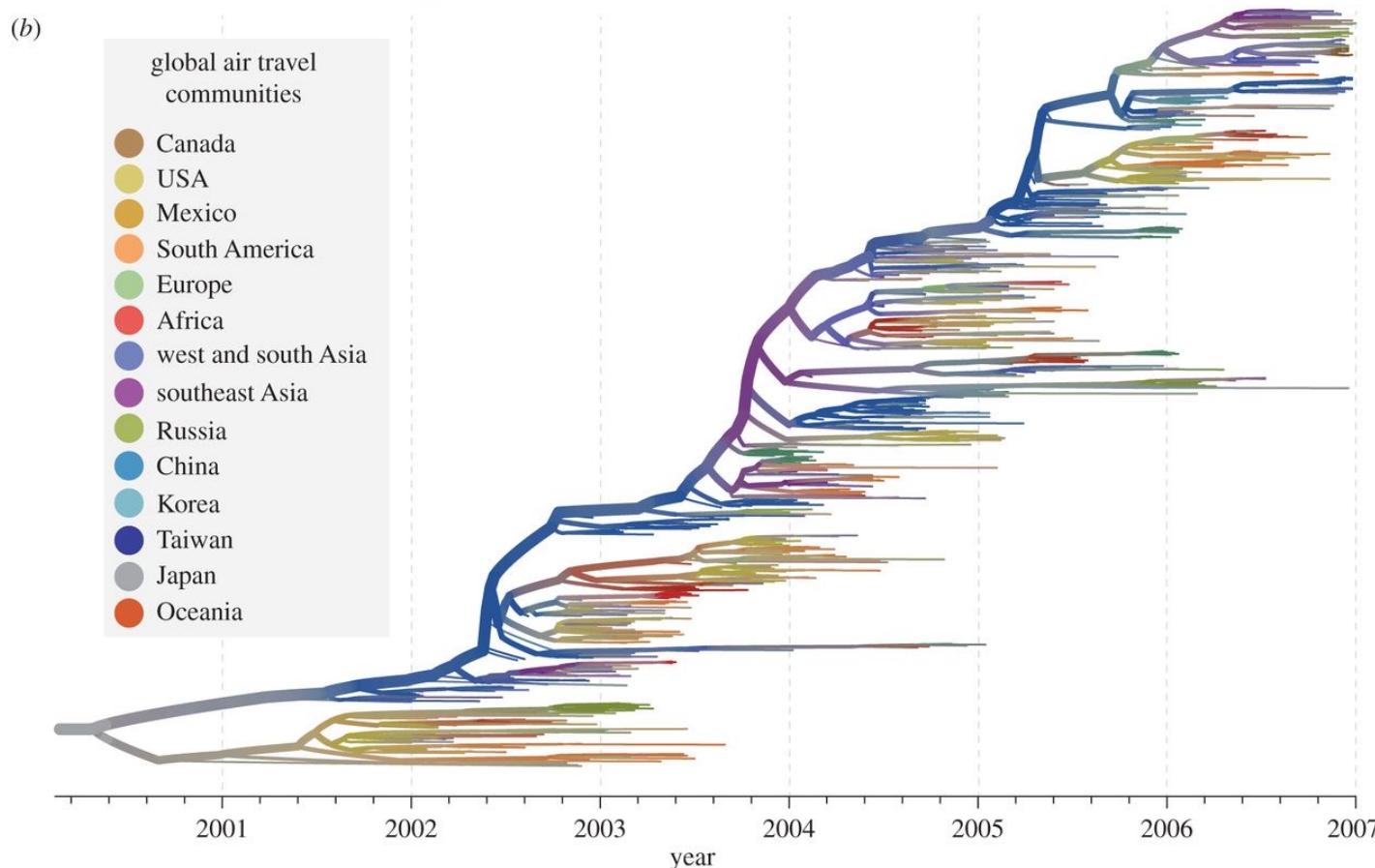
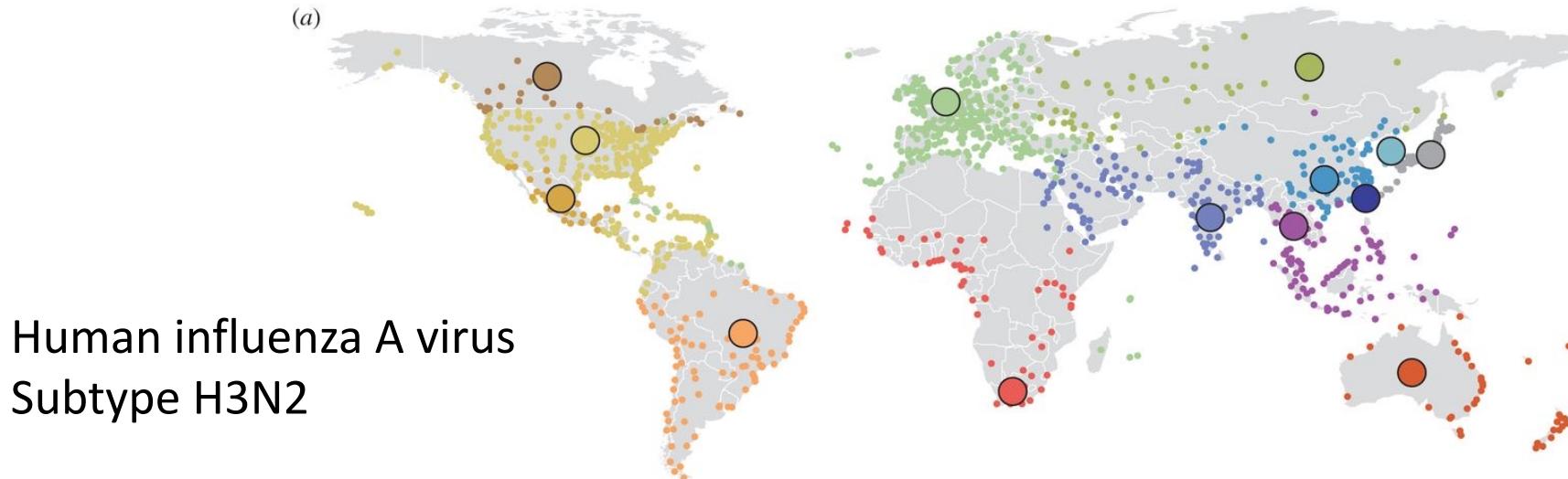
1859

Phylogenetic trees

- Topology (relationships)
- Branch lengths (amount of evolutionary change or time)









DOCS HELP LOGIN

Dataset

- ncov
- gisaid
- global

Date Range

2019-12-20 2021-07-21

▶ PLAY ⏪ RESET

Color By

- Clade

Filter Data

Type filter query here...

Tree Options

Layout

RECTANGULAR

RADIAL

UNROOTED

CLOCK

SCATTER

Genomic epidemiology of novel coronavirus - Global subsampling



Built with [nextstrain/ncov](#). Maintained by the [Nextstrain team](#). Enabled by data from [GISAID](#).

Showing 3977 of 3977 genomes sampled between Dec 2019 and Jul 2021.

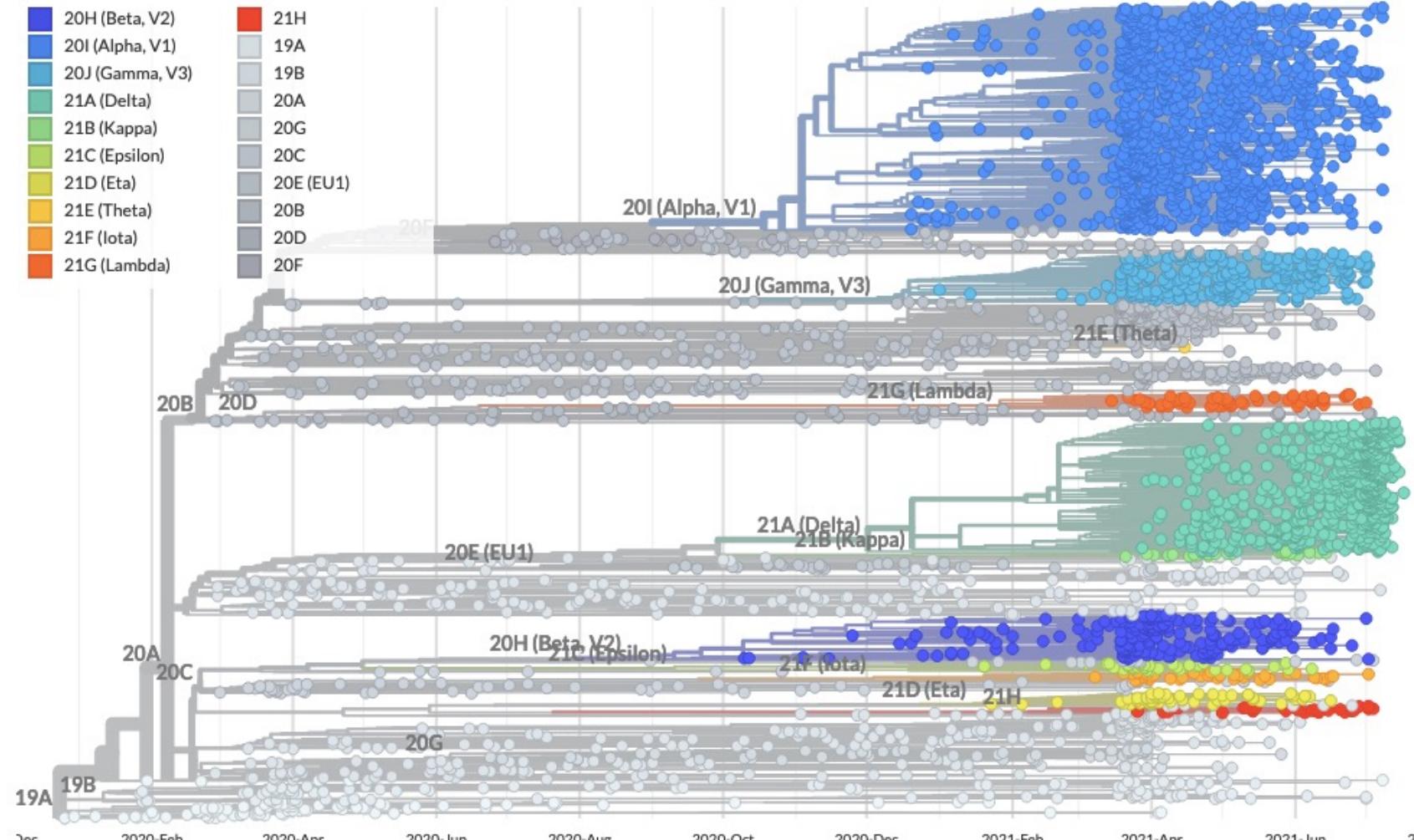
ZOOM TO SELECTED

RESET LAYOUT

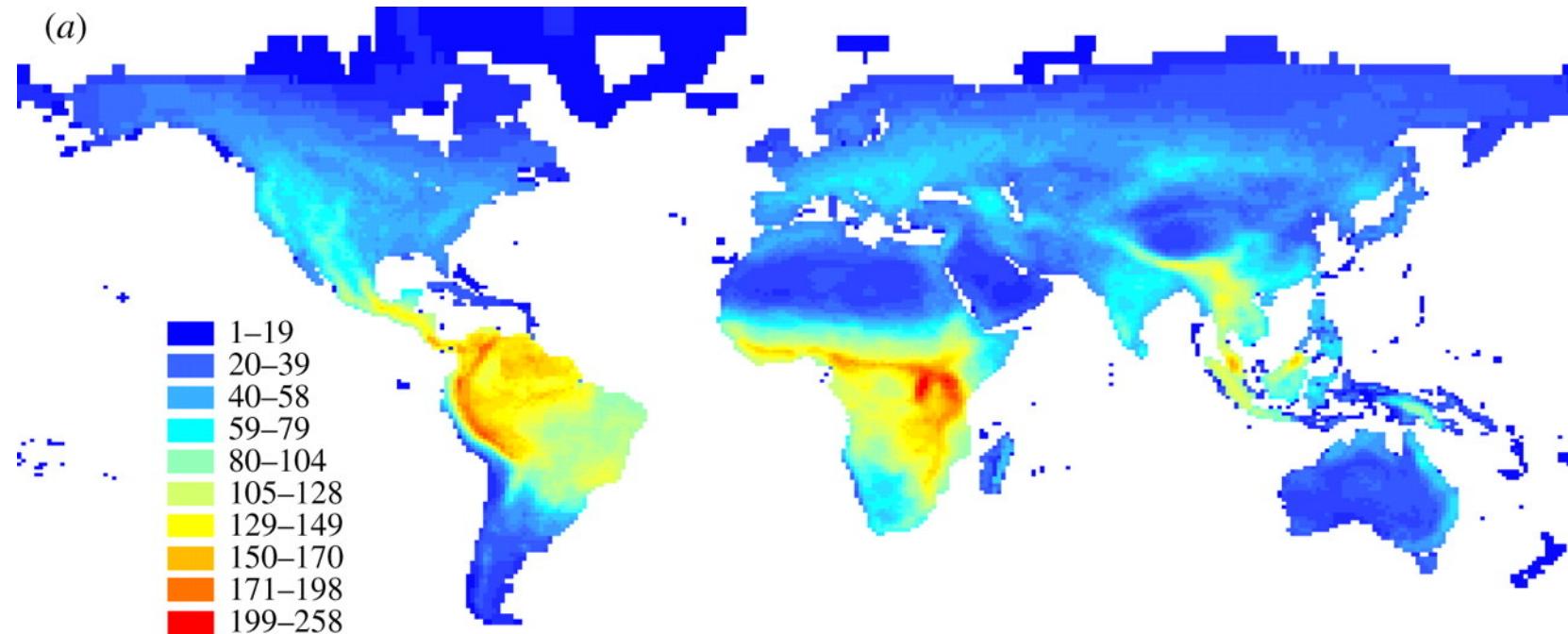
Phylogeny

Clade ▲

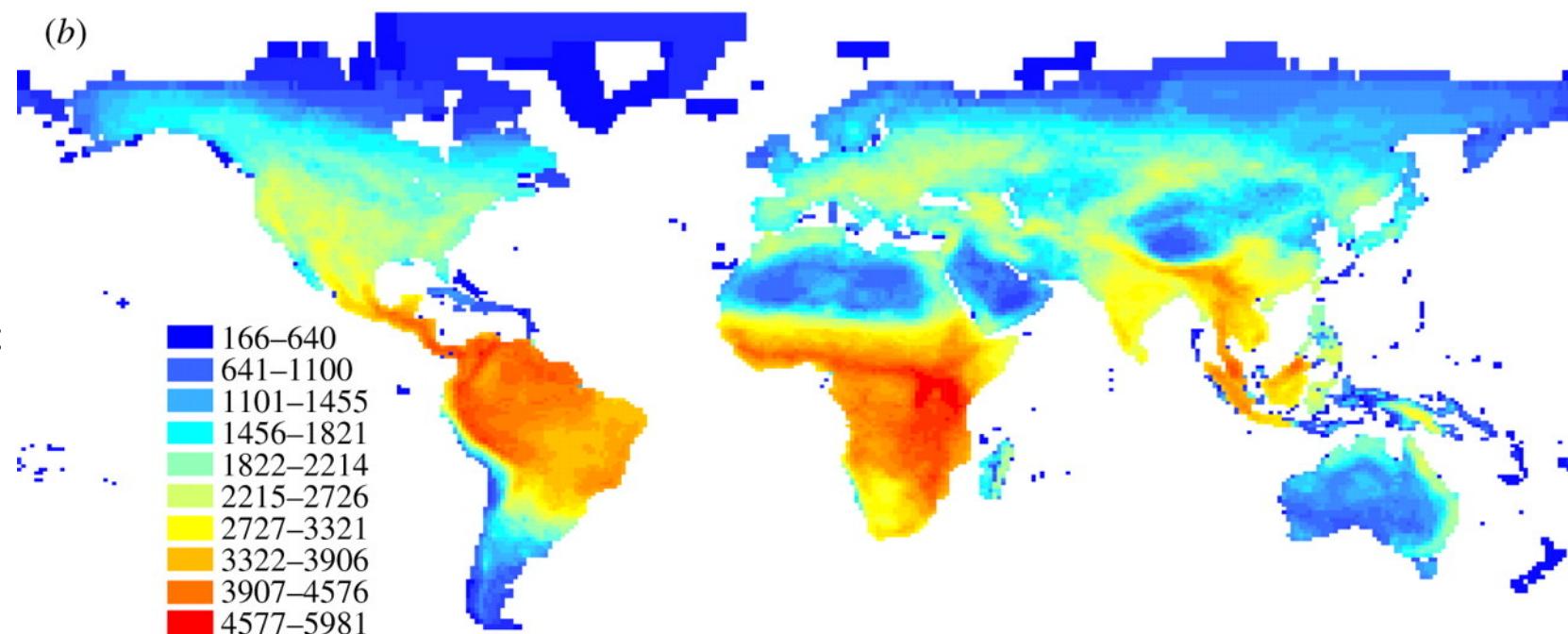
20H (Beta, V2)	21H
20I (Alpha, V1)	19A
20J (Gamma, V3)	19B
21A (Delta)	20A
21B (Kappa)	20G
21C (Epsilon)	20C
21D (Eta)	20E (EU1)
21E (Theta)	20B
21F (Iota)	20D
21G (Lambda)	20F



Mammal
species
richness

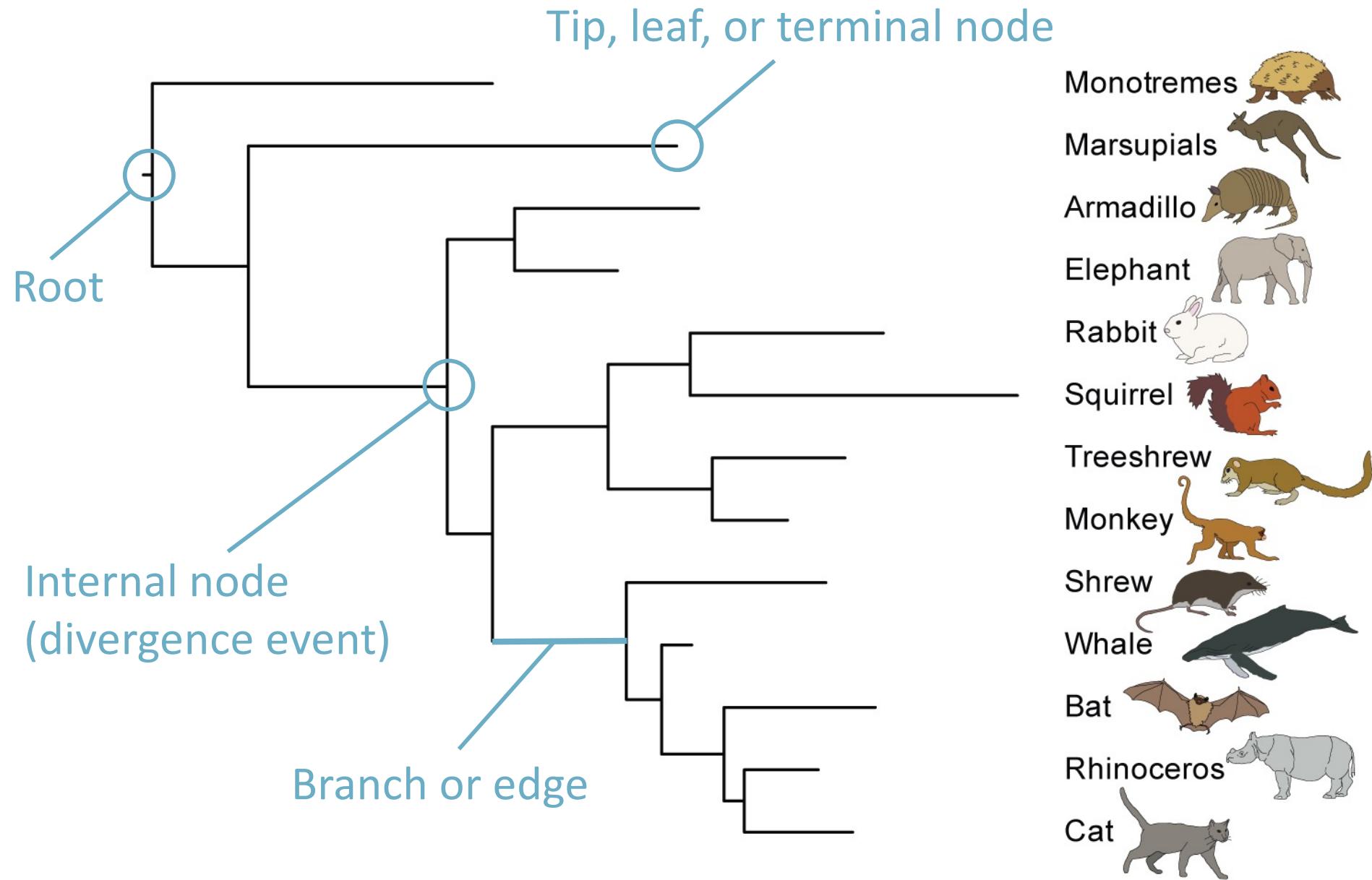


Mammal
phylogenetic
diversity

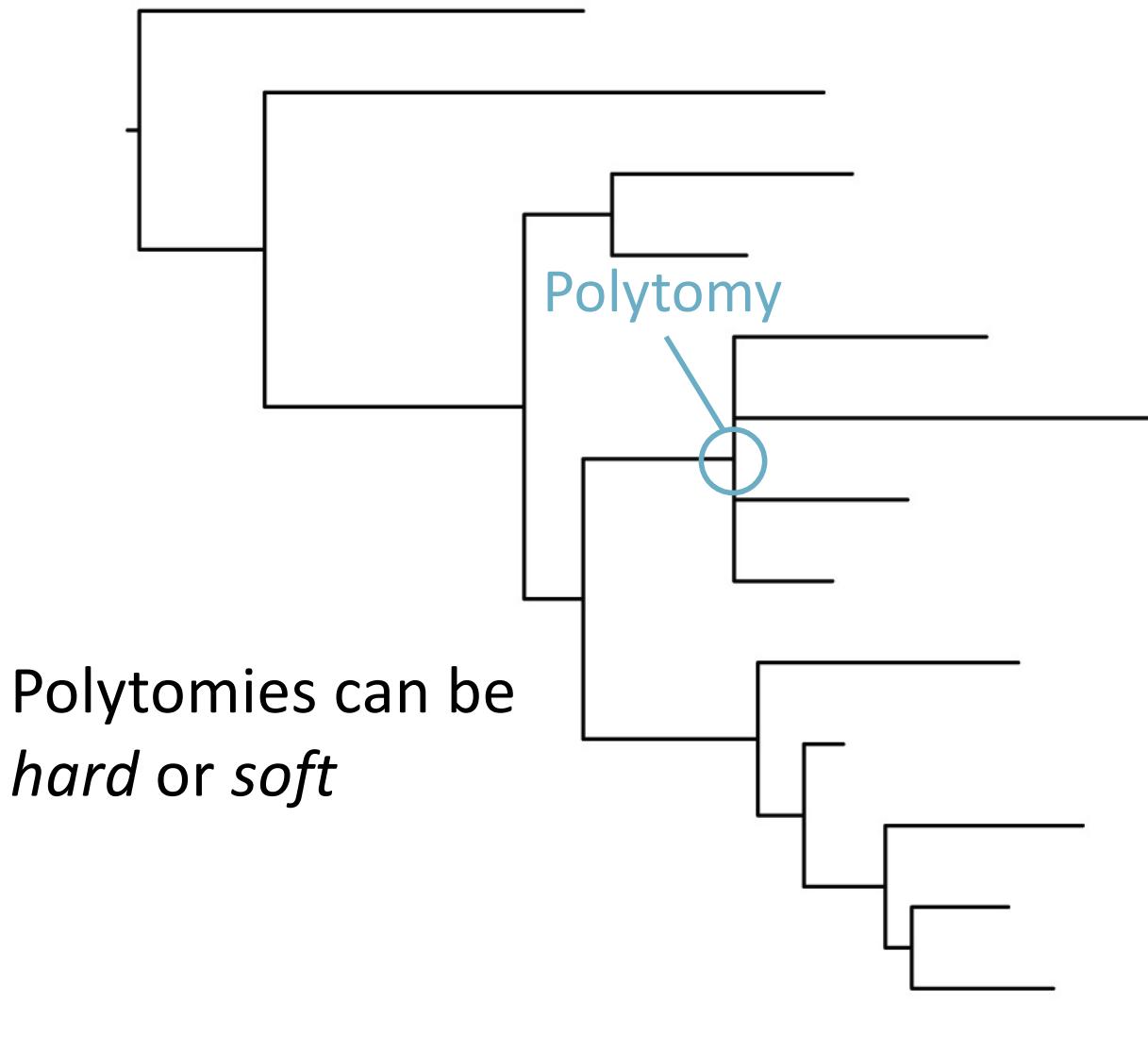


Tree Thinking

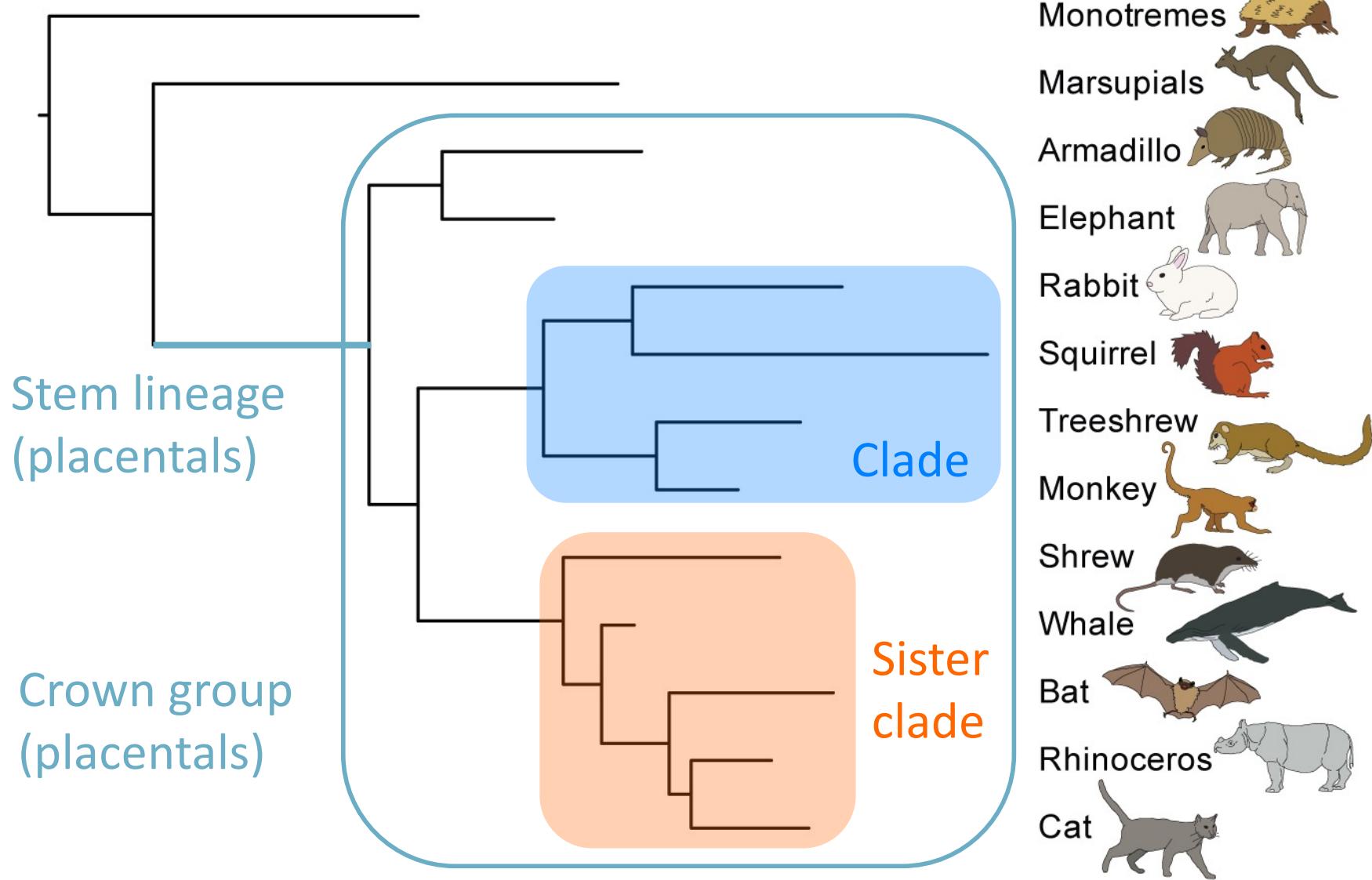
Phylogenetic trees



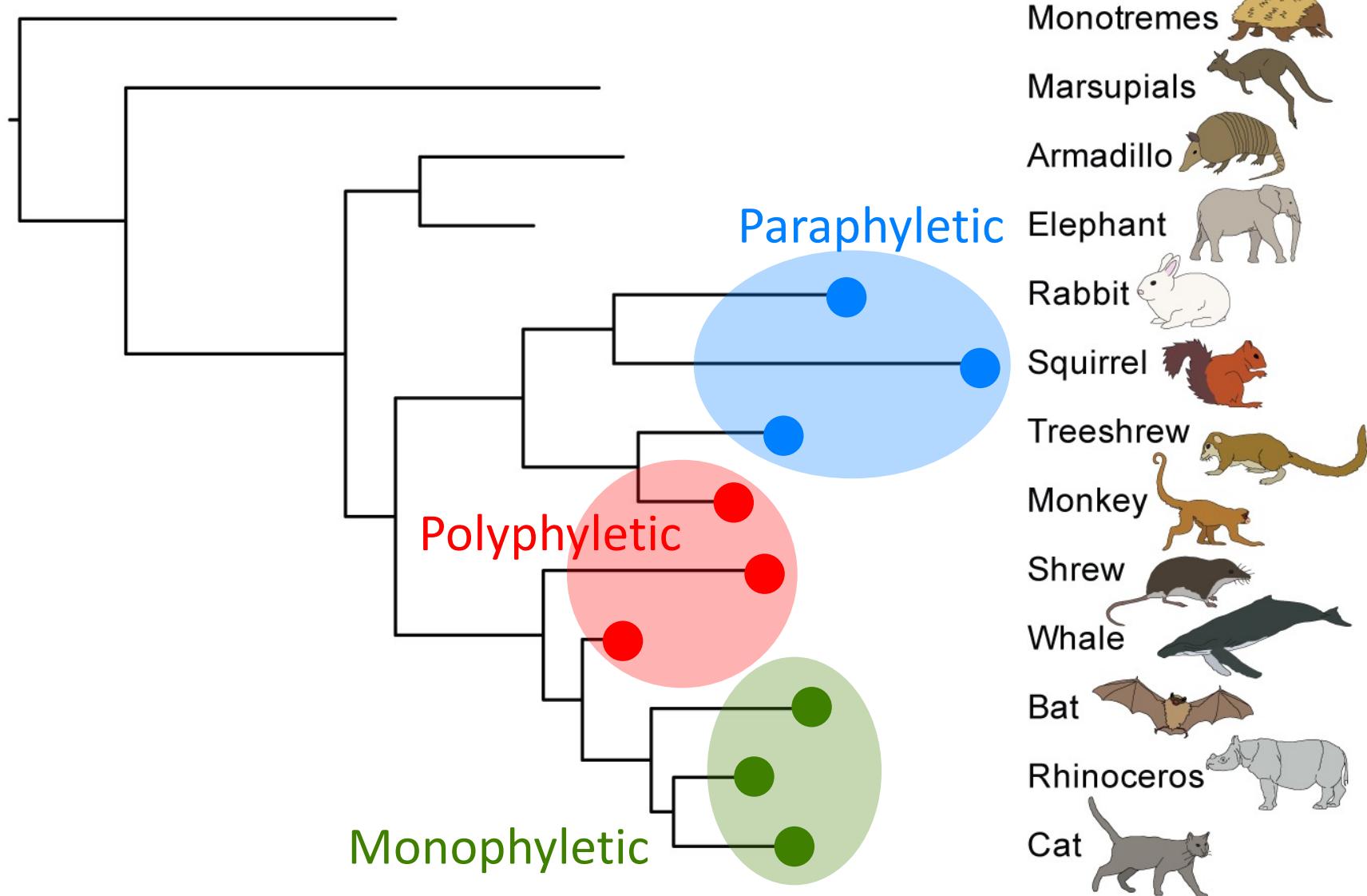
Phylogenetic trees



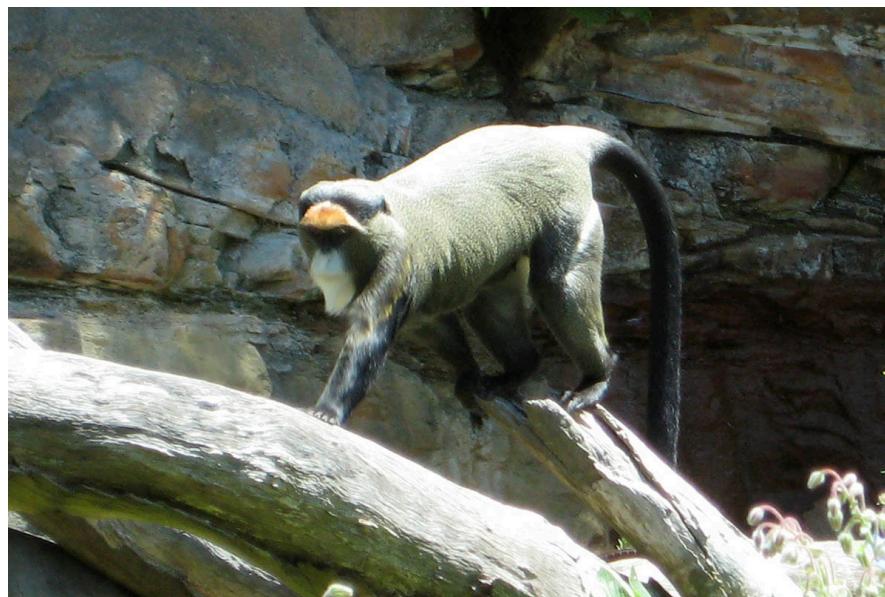
Phylogenetic trees



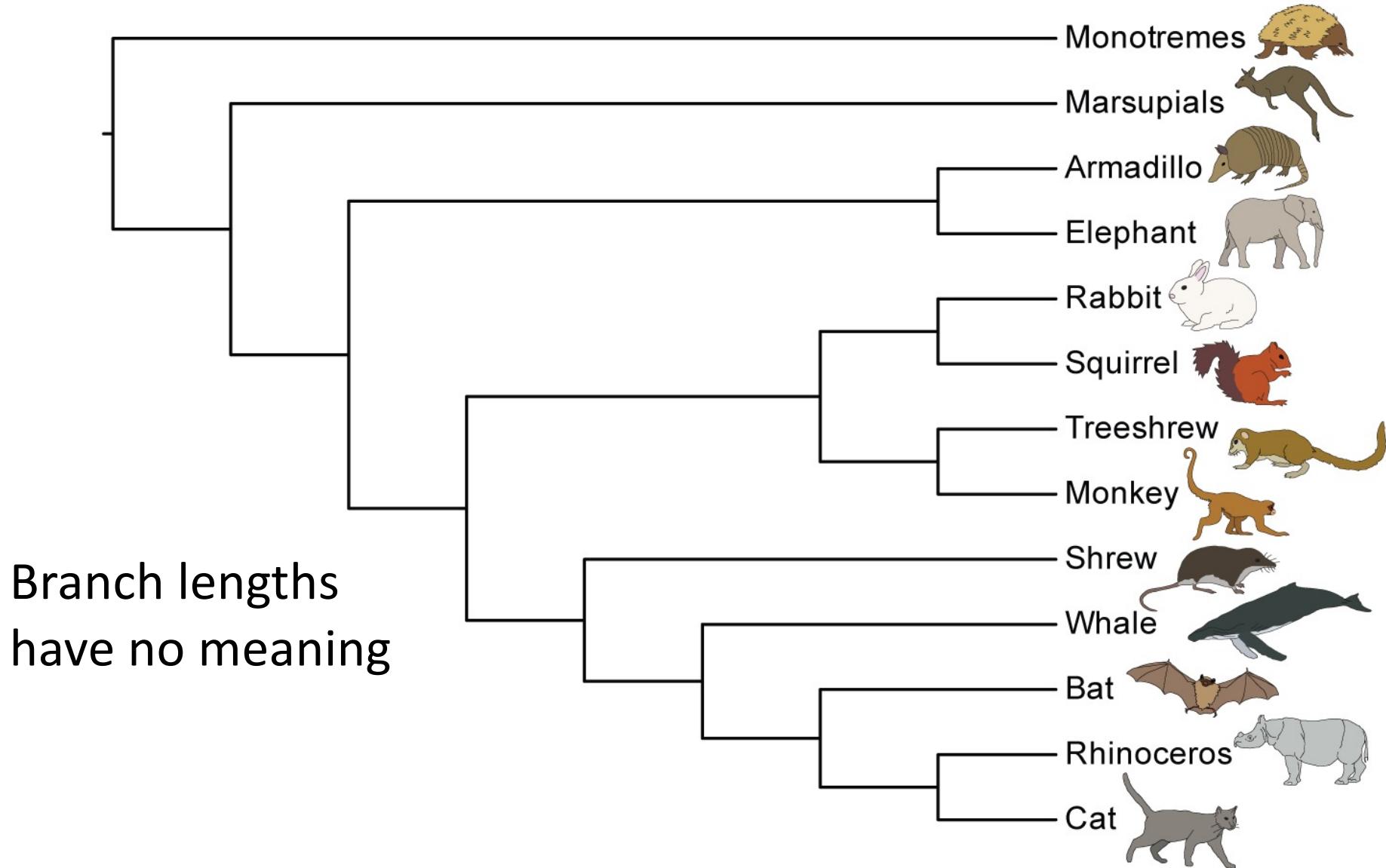
Cladistic terms



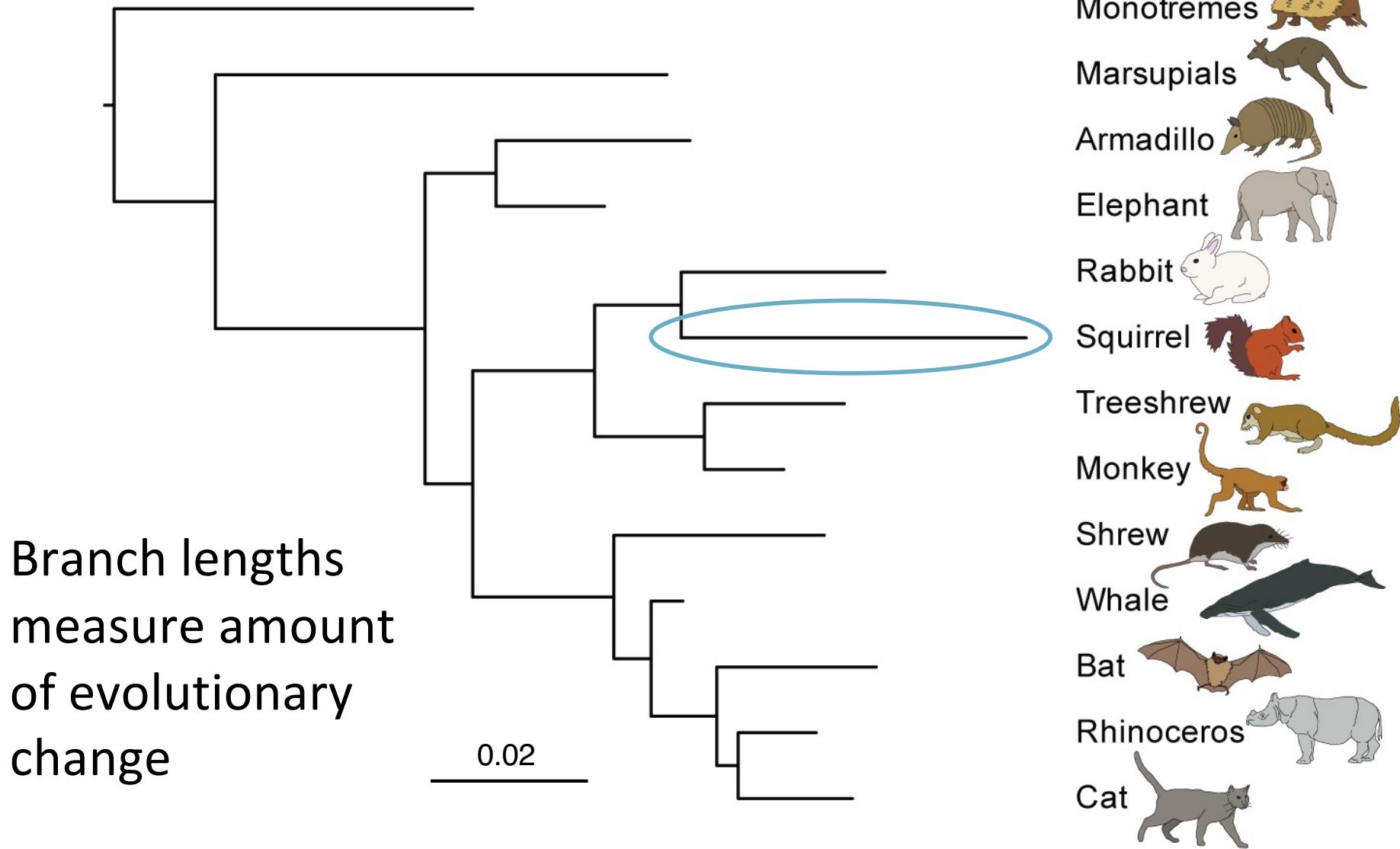
Paraphyletic groups



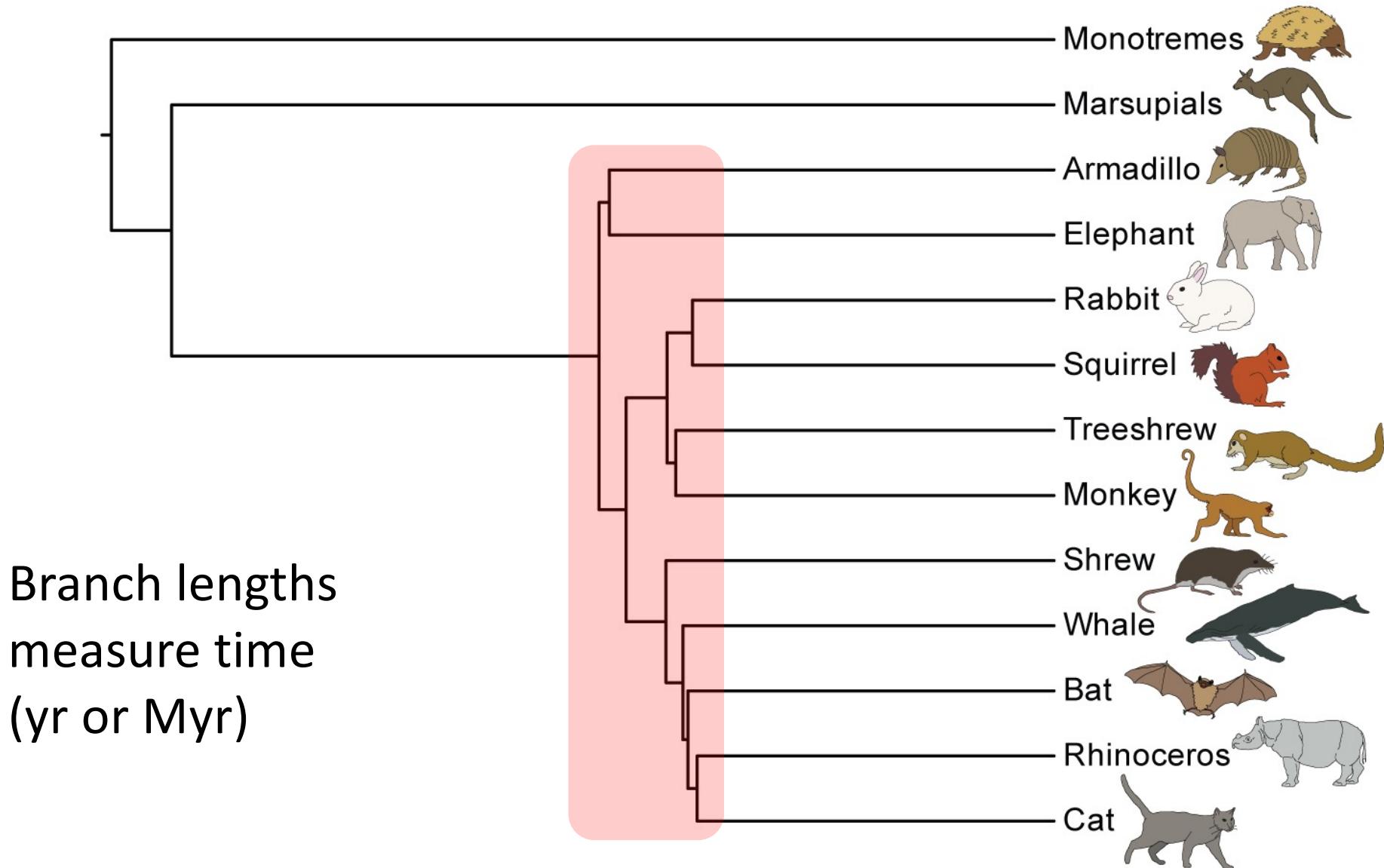
Trees: Cladogram



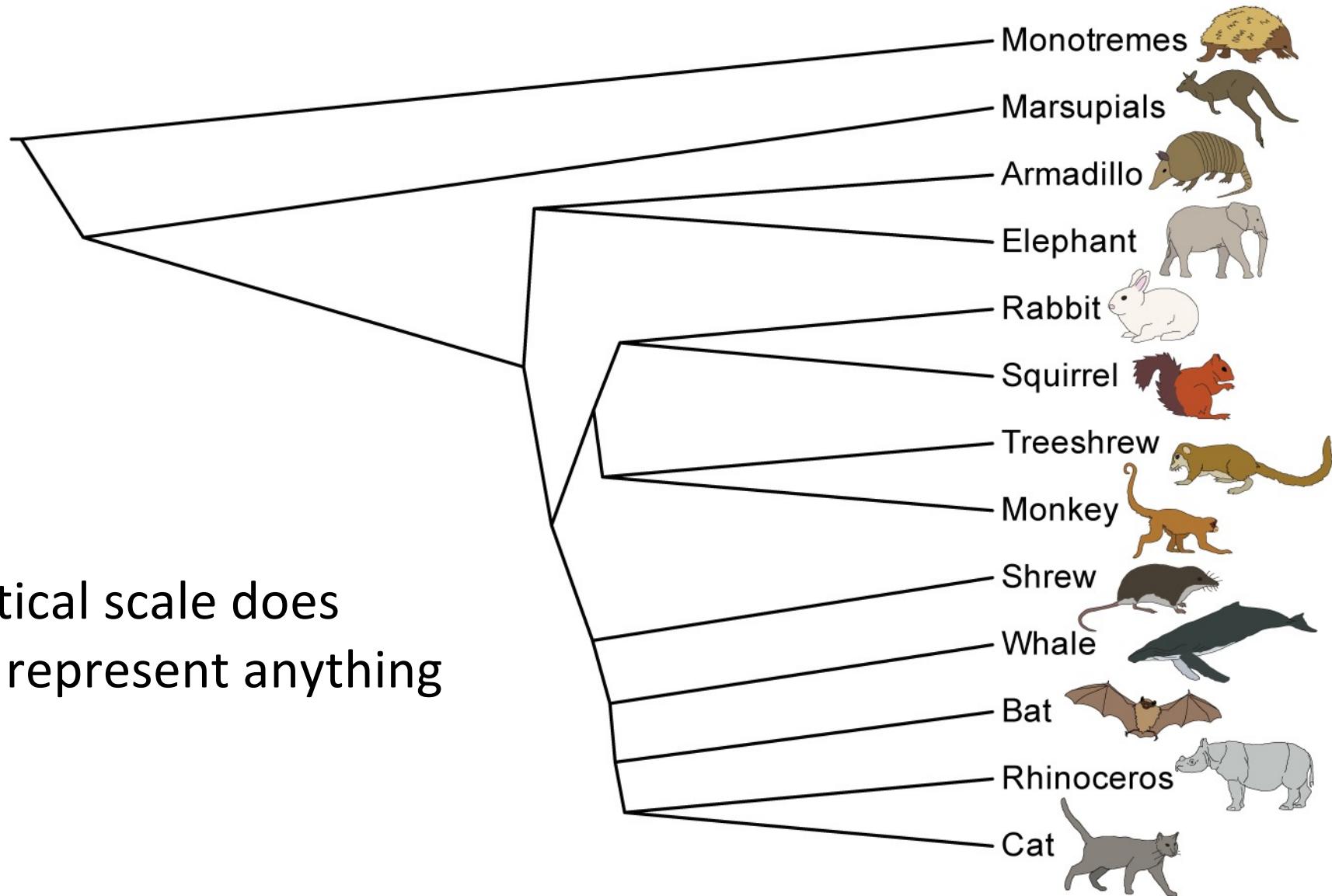
Trees: Phylogram



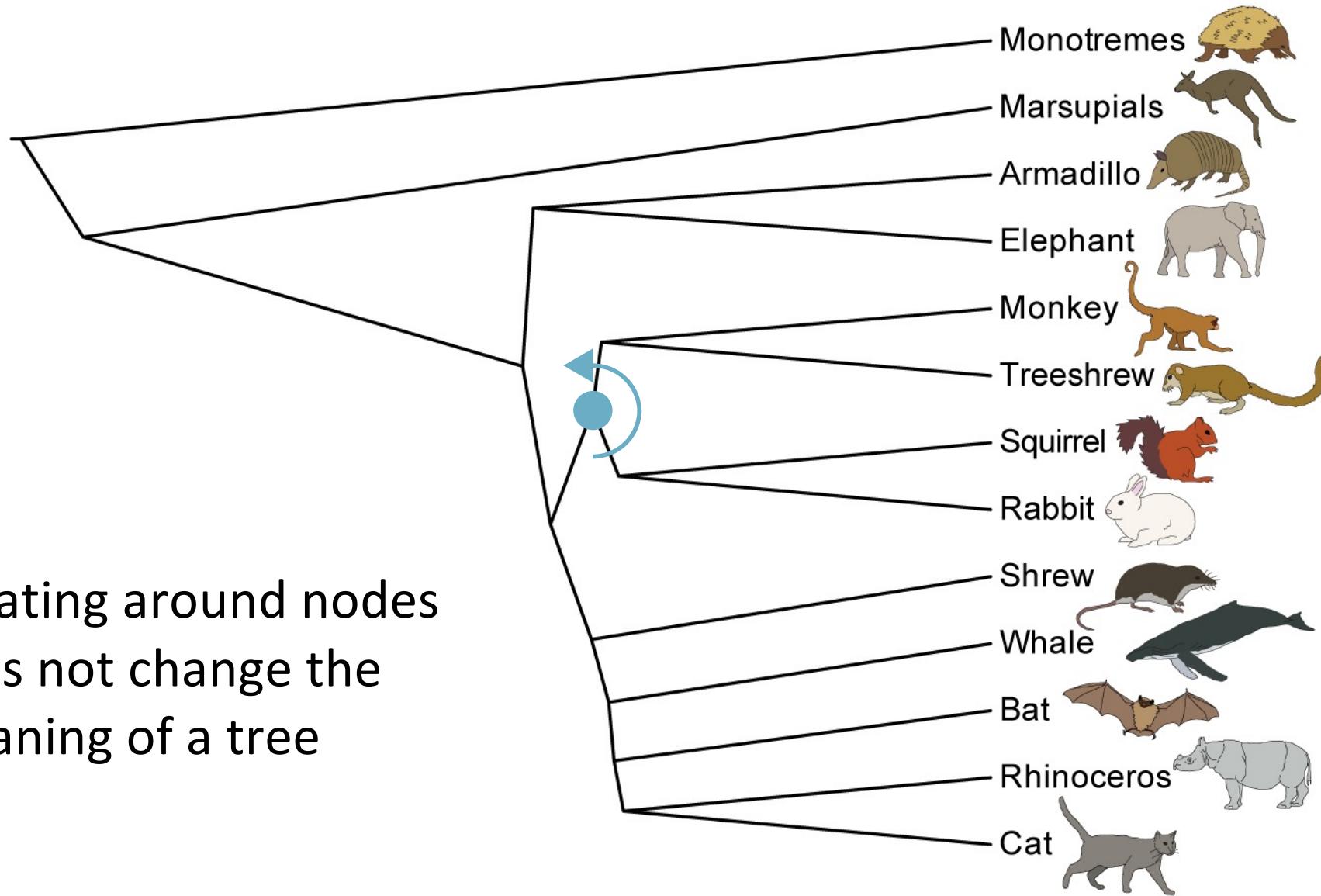
Trees: Chronogram or time-tree



Phylogenetic trees



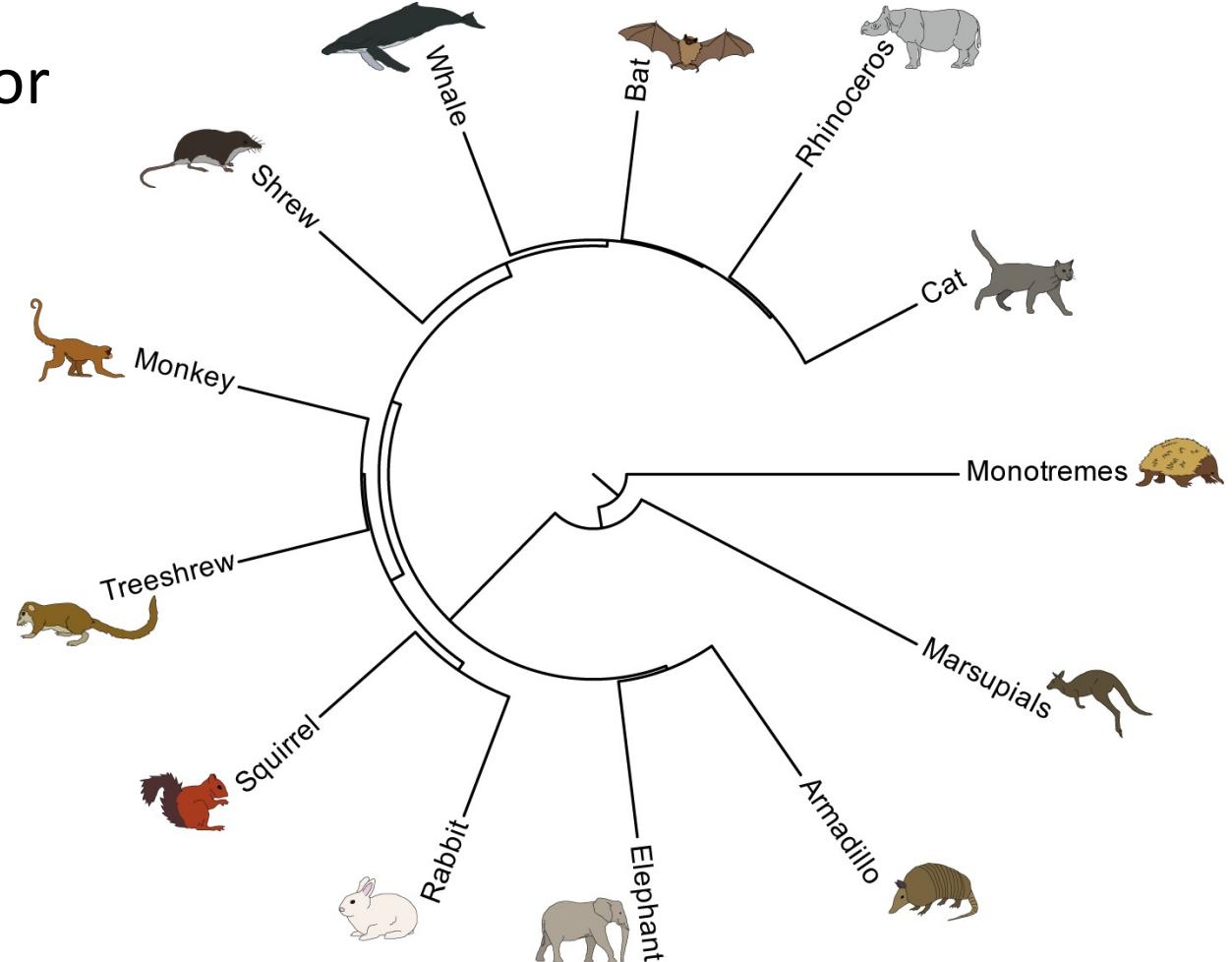
Phylogenetic trees



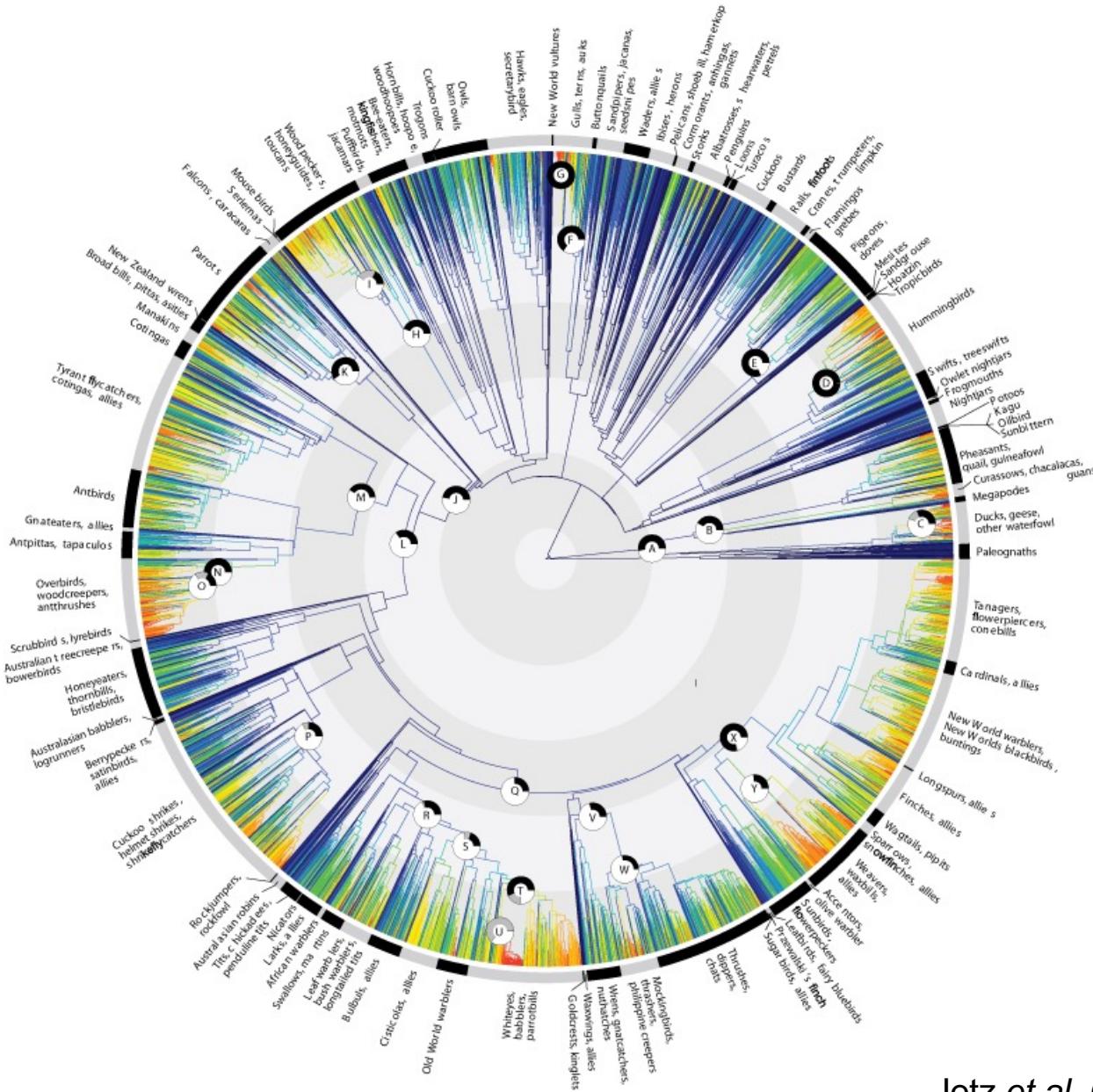
Rotating around nodes
does not change the
meaning of a tree

Phylogenetic trees: Circular

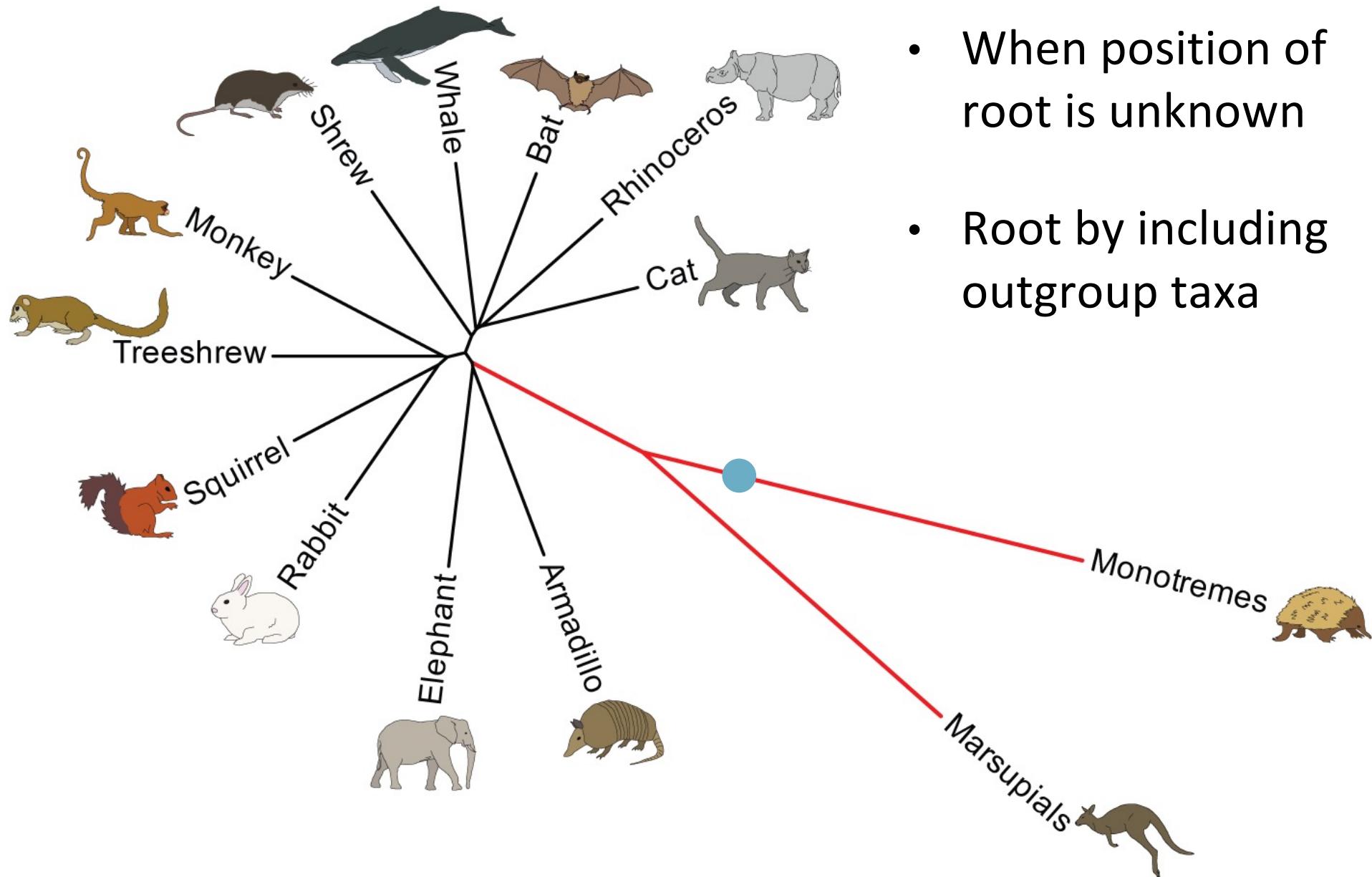
- Root is placed in centre
- Cladogram, phylogram, or chronogram
- Often used to display large trees
- Difficult to interpret



Phylogenetic trees: Circular



Phylogenetic trees: Unrooted



Rooting

- **Include outgroup taxa**
 - Taxon closely related to ingroup
 - Taxon is not part of ingroup
- **Root at midpoint**
 - Highly unreliable if internal branches are short
- **Use a molecular clock**
 - Phylogenetic analysis infers a rooted tree

Phylogenetic trees: Newick format

- Without branch lengths (cladogram):
 - (Monotremes,(Marsupials,((Elephant,Armadillo),(((Squirrel,Rabbit),(Monkey,Treeshrew)),(Shrew,(Whale,(Bat,(Cat,Rhinoceros)))))));
- With branch lengths (phylogram/chronogram):
 - (Monotremes:12.0,(Marsupials:11.0,((Elephant:1.0,Armadillo:1.0):9.0,(((Squirrel:1.0,Rabbit:1.0):2.0,(Monkey:1.0,Treeshrew:1.0):2.0):5.0,(Shrew:4.0,(Whale:3.0,(Bat:2.0,(Cat:1.0,Rhinoceros:1.0):1.0):1.0):4.0):2.0):1.0):1.0);

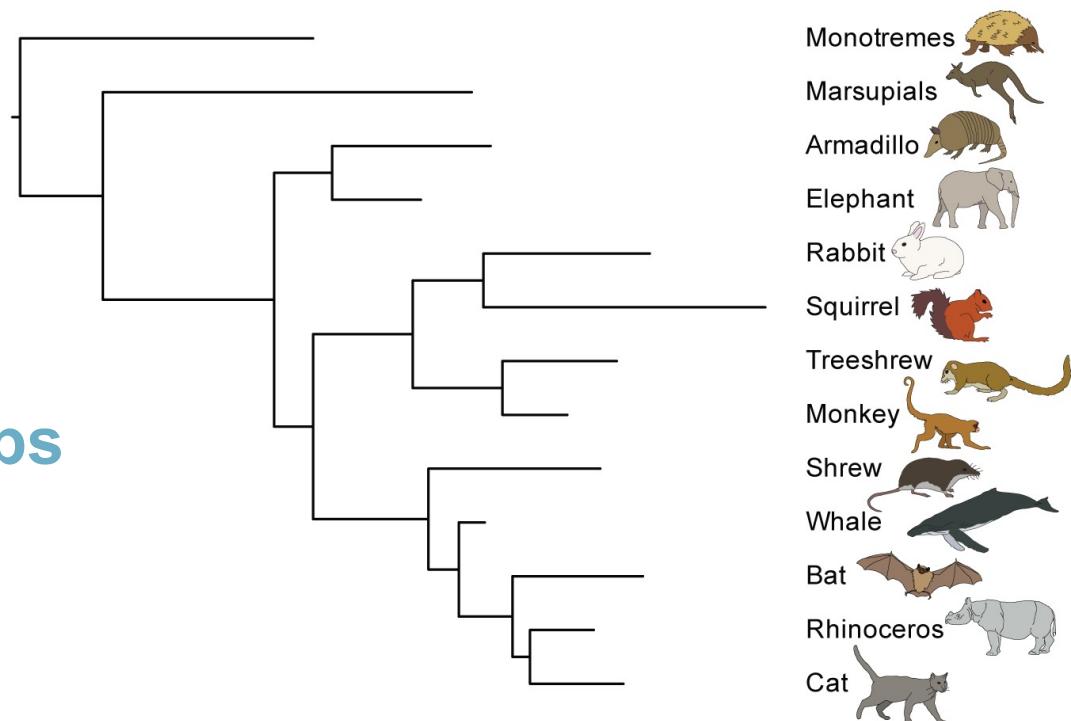
Molecular Phylogenetics

Phylogenetic analysis

- Sometimes we know the phylogeny
 - Viral transmission histories
 - Pedigrees (humans, domesticated animals, lab organisms, etc.)
- Usually we must analyse data from present-day organisms to infer phylogenies

Fundamental assumptions

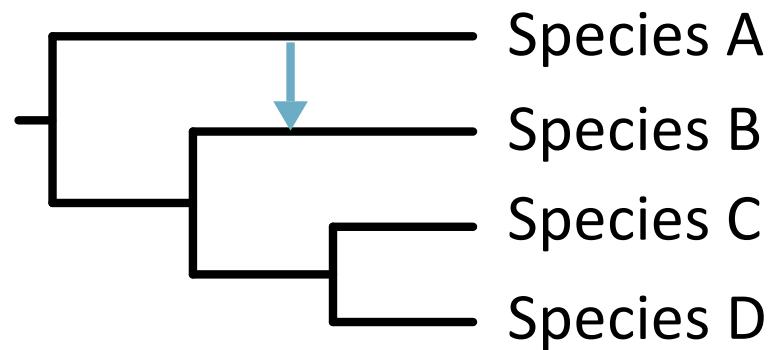
- Phylogenetic methods make several fundamental assumptions:
 - Relationships among taxa can be represented by a tree
 - Homologous characters are being compared
 - Characters are mutually independent



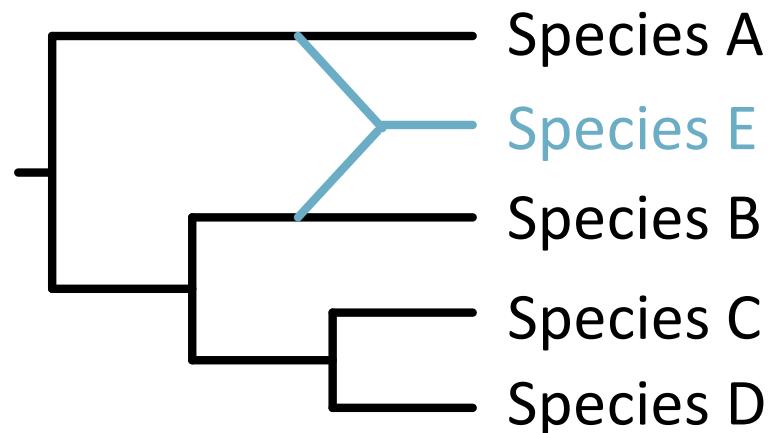
When might relationships
not be treelike?

Non-treelike evolution

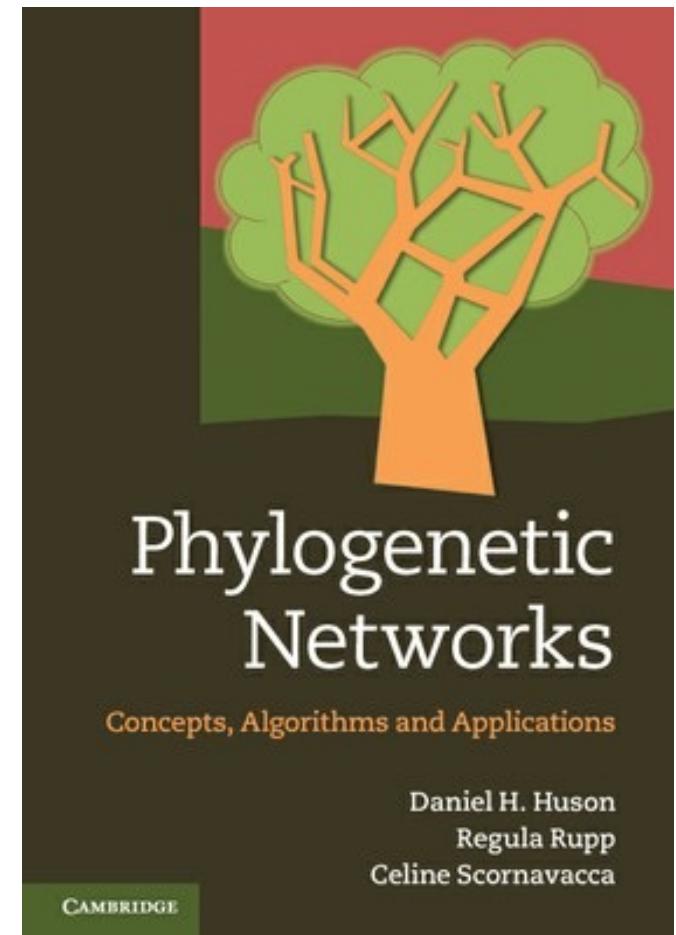
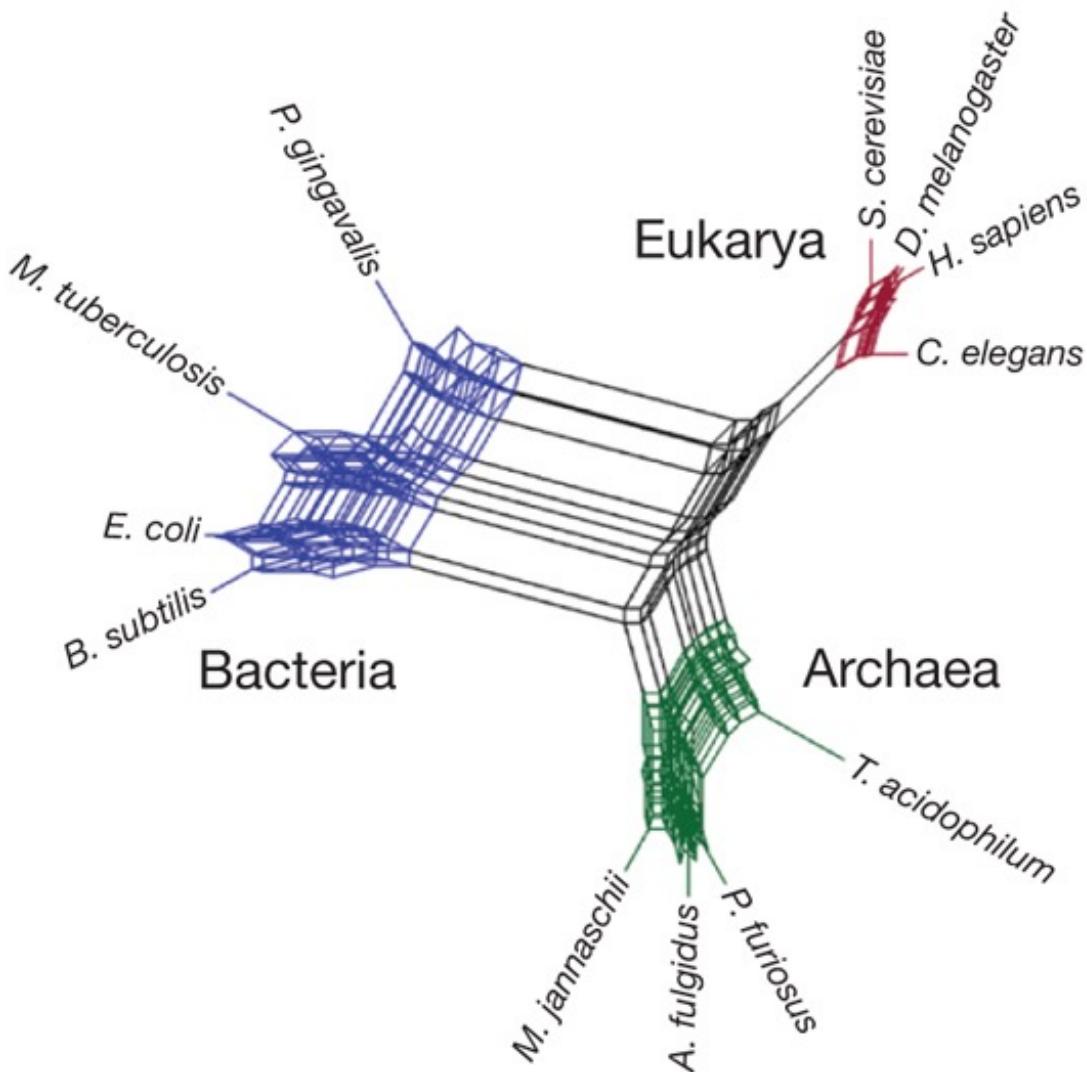
Horizontal gene transfer



Hybrid speciation

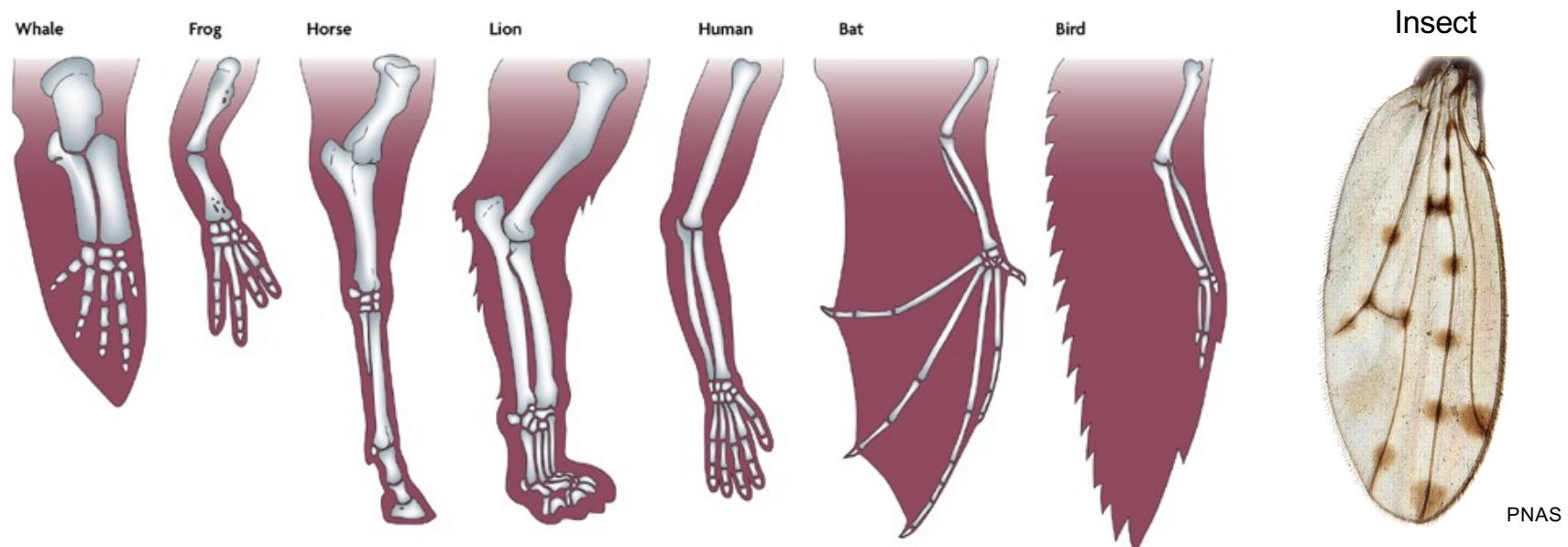


Phylogenetic networks



Fundamental assumptions

- Phylogenetic methods make several fundamental assumptions:
 - Relationships among taxa can be represented by a tree
 - Homologous characters are being compared
 - Characters are mutually independent



Character homology

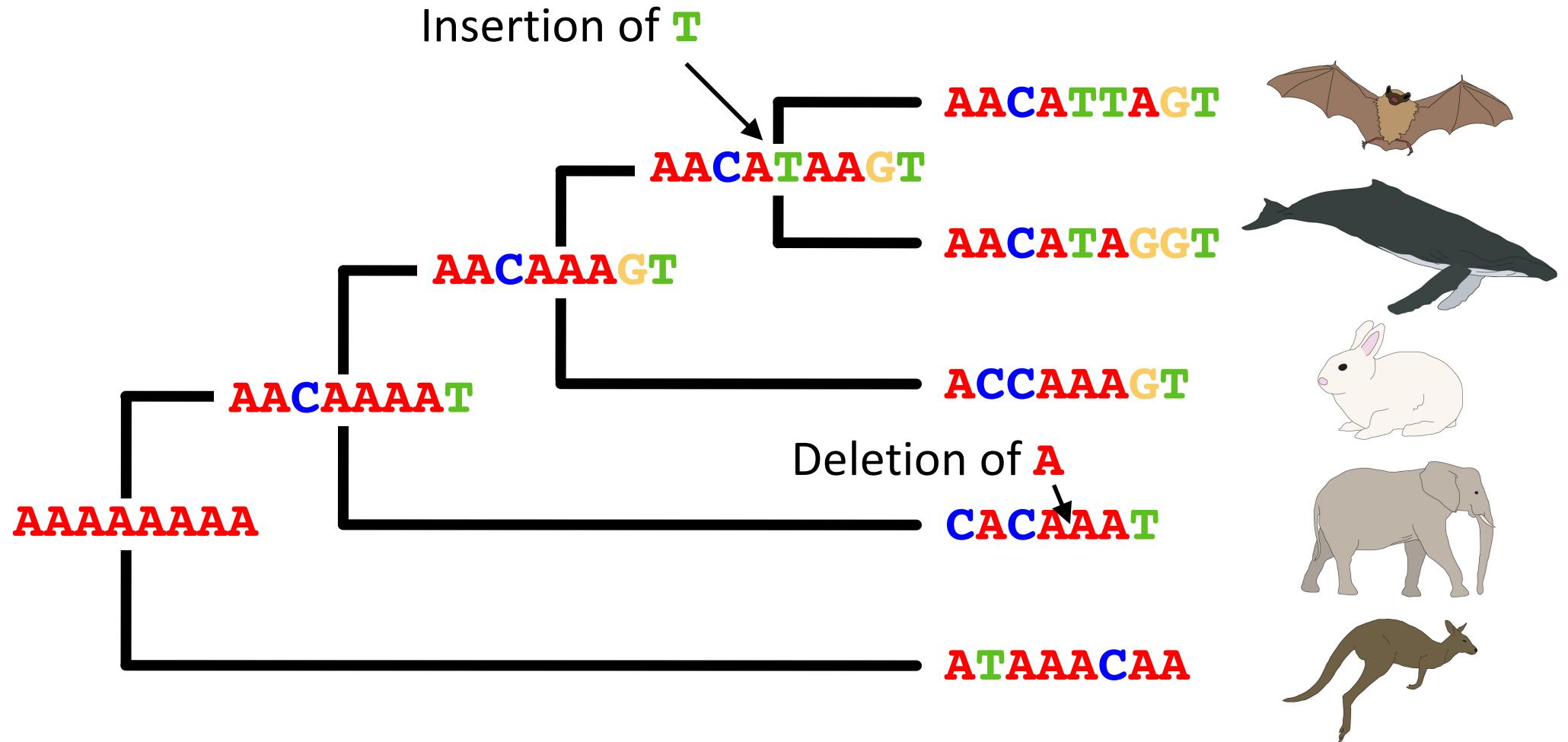
- Comparing strings of nucleotides (or amino acids)
- Each nucleotide site is a character
- But DNA sequences can vary in length

bat
whale
rabbit
elephant
kangaroo

CGTTAGTACACT
CGATAGTTCACT
CGTTAGTTTACC
CATTGGATTACT
CATTGGTTTACT



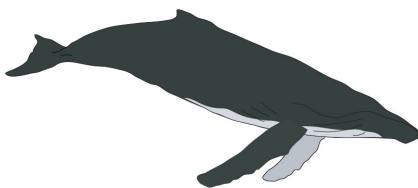
DNA sequence evolution



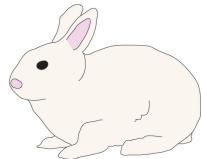
DNA sequence alignment



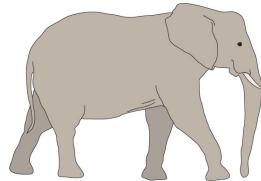
AACATTAGT



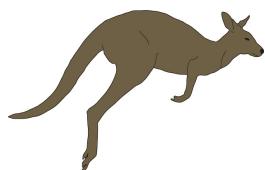
AACATAGGT



ACCAAAAGT



CACAAAT



ATAAACAA



AACATTAGT

AACATAGGT

ACCA-AAGT

CACA--AAT

ATAA-ACAA

DNA sequence alignment

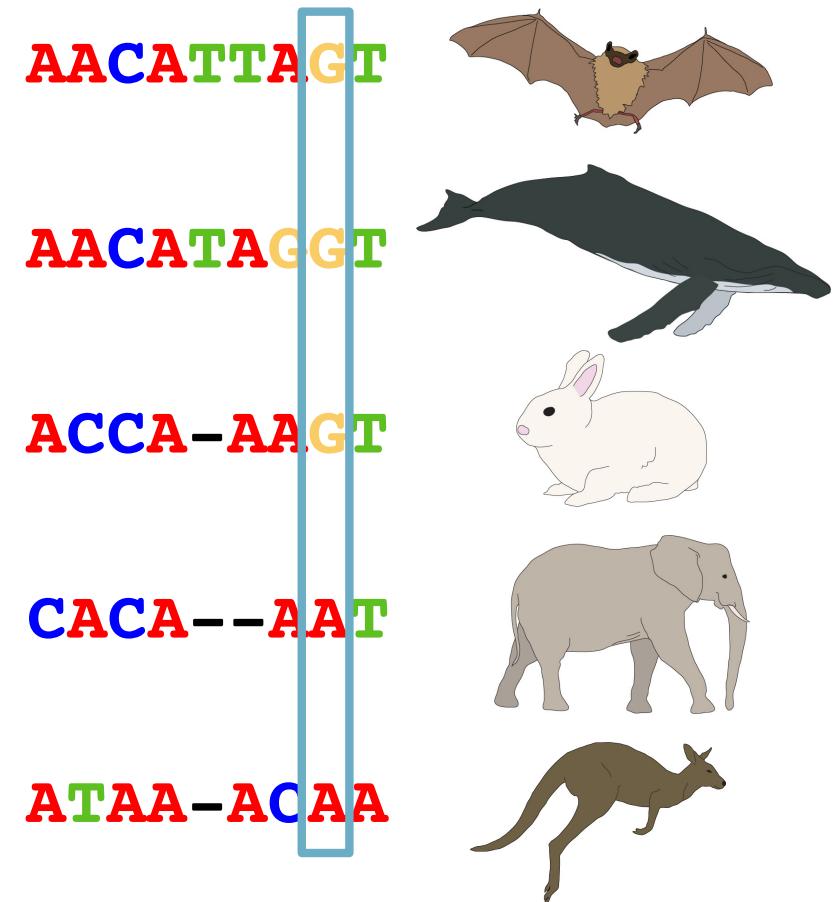
- Homologous site
- Inherited from the common ancestor of all sequences in the alignment
- The aim of sequence alignment is to maximise the number of sites for which you can infer homology

AACATTAGT
AACATAGGT
ACCA-AAGT
CACA--AAT
ATAA-ACAA



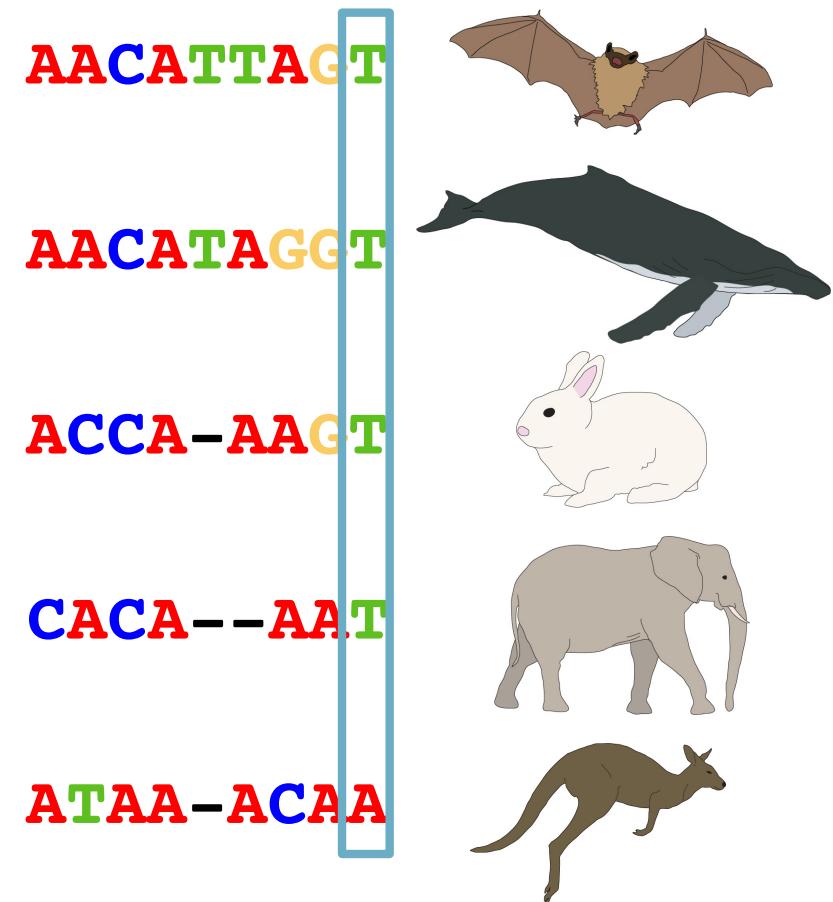
DNA sequence alignment

- Groups together the first 3 sequences
- Groups together the last 2 sequences
- Informative for all phylogenetic methods



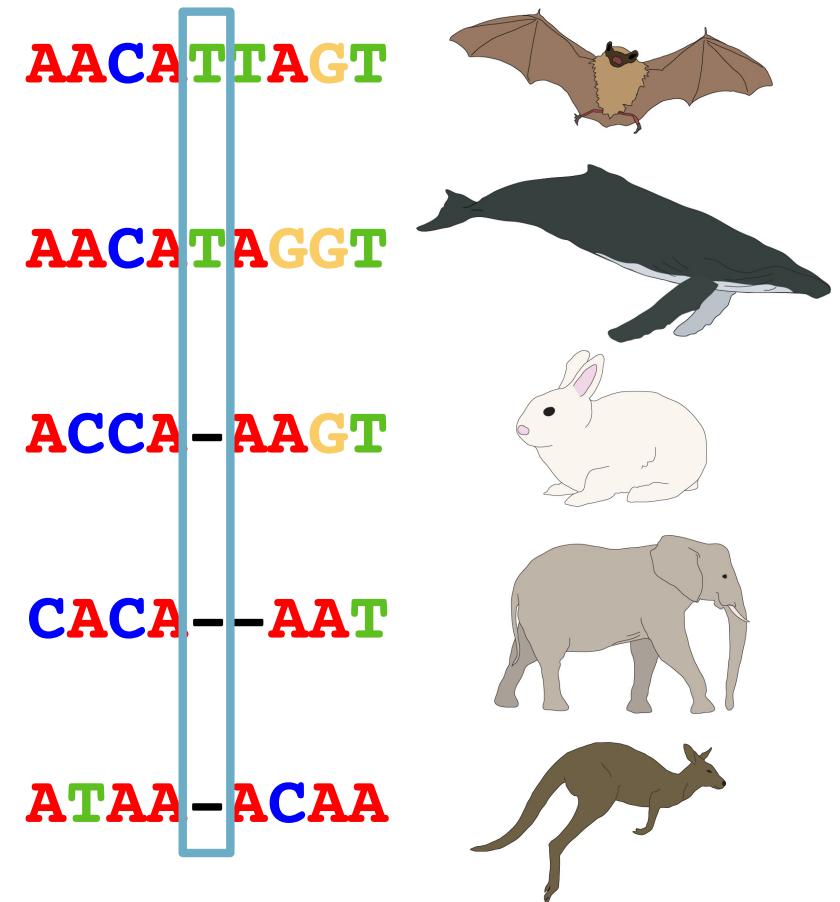
DNA sequence alignment

- Does not group any sequences
 - Not useful for maximum parsimony
- But informative for estimating amount of evolutionary change
 - Useful for other methods



DNA sequence alignment

- Indel – insertion or deletion
- Potentially informative
- Most phylogenetic methods do not really use indel data



A practical approach

Align sequences using automated methods

CLUSTAL W: improving the sensitivity of progressive multiple sequence alignment through sequence weighting, position-specific gap penalties and weight matrix choice

Julie D.Thompson, Desmond G.Higgins⁺ and Toby J.Gibson*

Software

Open Access

MUSCLE: a multiple sequence alignment method with reduced time and space complexity

Robert C Edgar*

MAFFT: a novel method for rapid multiple sequence alignment based on fast Fourier transform

Kazutaka Katoh, Kazuharu Misawa¹, Kei-ichi Kuma and Takashi Miyata*

A practical approach

Align sequences using automated methods



Adjust alignments by eye

CTATGTGGCACCCAGCCCCATGCA--AGC

ATATGTGGCA-----CCCAGGGCA--AG-

ATATGTGGCACCCAGCCCCATGCATTT--

A practical approach

Align sequences using automated methods



Adjust alignments by eye

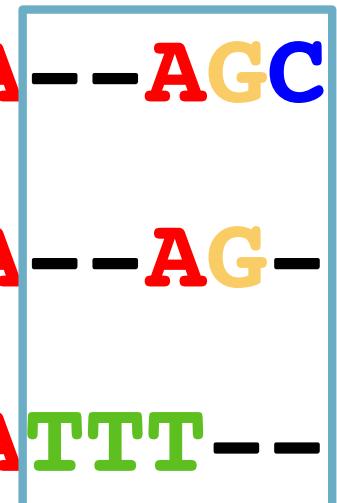


Delete sites with uncertain homology

CTATGTGGCACCCAGCCCCATGCA -- AGC

ATATGTGGCA ----- CCCAGGGCA -- AG -

ATATGTGGCACCCAGCCCCATGCA TTT --



?

Useful references

