

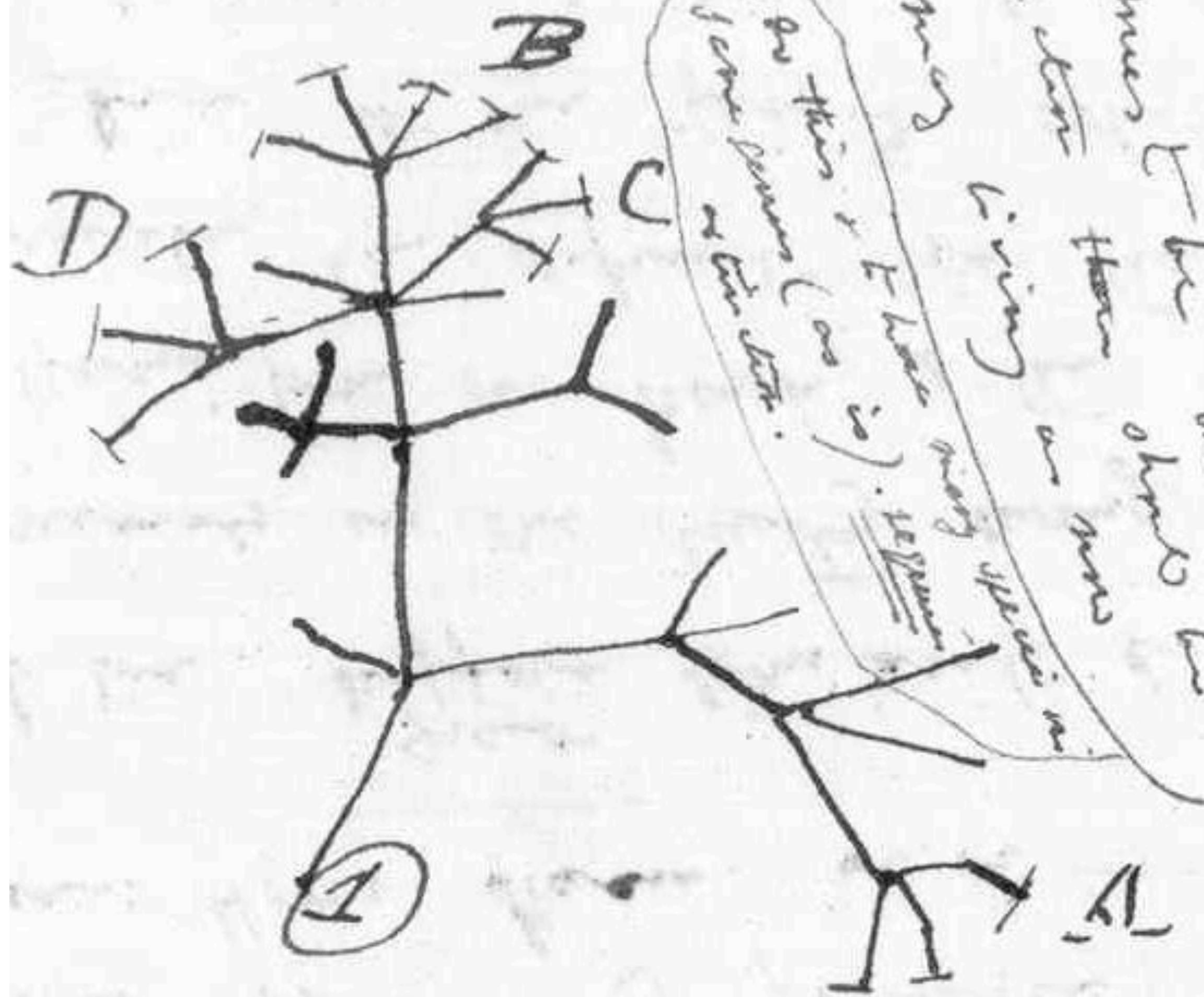
# Phylogenetic Trees

Mark Stenglein, MIP 280A4

36

I think there are  
more men than women  
living among them in  
one house.

Do you think it is so?



I think

# Phylogenetic trees allow you to answer important questions

 Yassir Lester ✅  
@Yassir\_Lester

Yo real talk are bears dogs or cats

2:01 PM · Apr 2, 2020 · Twitter Web App

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73 Retweets 712 Likes

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 Kumail Nanjiani ✅ @kumailn · 2h  
Replying to @Yassir\_Lester  
dogs

Comment 8Retweet 1Like 192Share

 Yassir Lester ✅ @Yassir\_Lester · 2h  
Clearly

Comment 1RetweetLike 11Share

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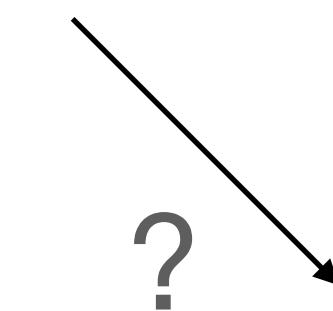
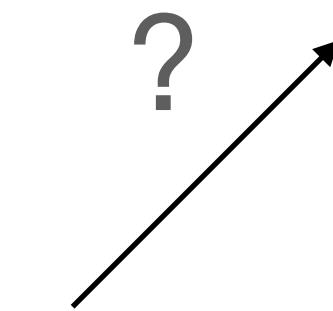
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 broti gupta ✅ @BrotiGupta · 2h  
Replying to @Yassir\_Lester  
Neither they are people in bear costumes

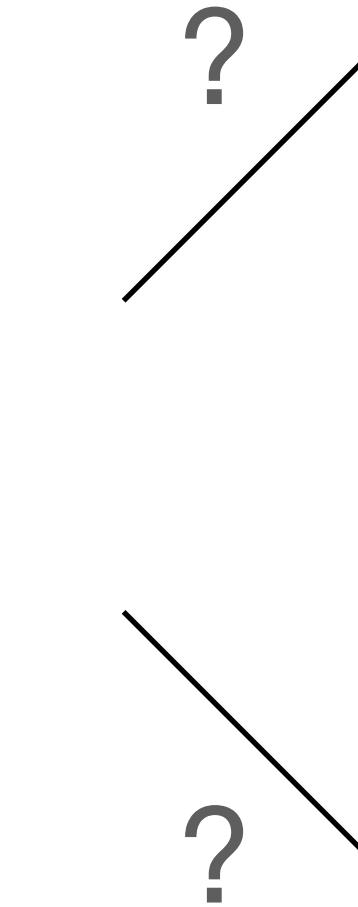
Comment 2Retweet 3Like 43Share

 Yassir Lester ✅ @Yassir\_Lester · 2h  
Ok

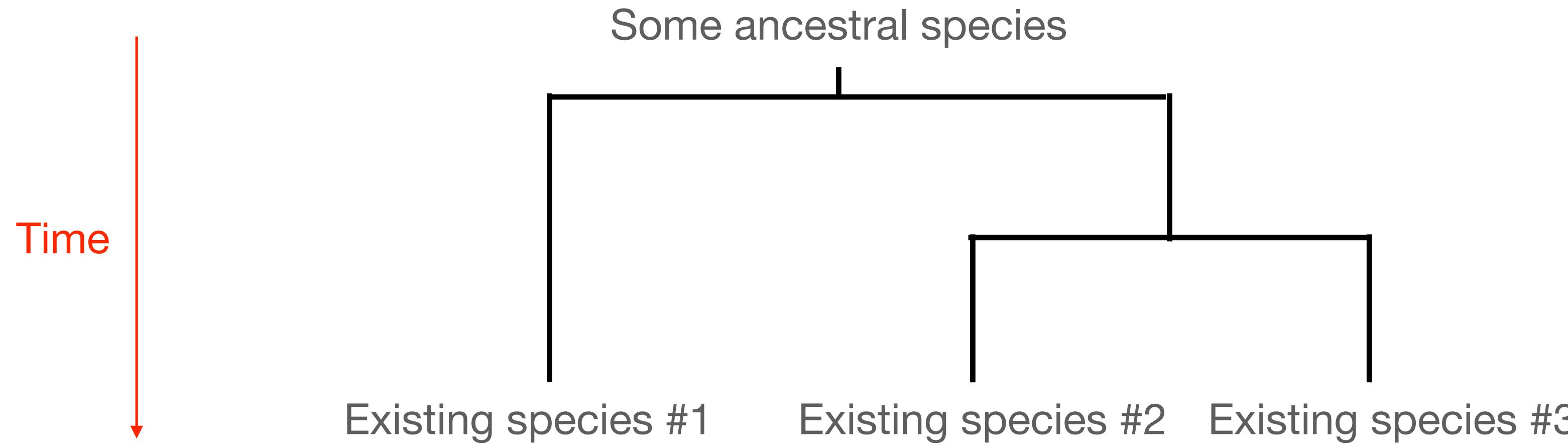
So, are bears cats or dogs?  
(Are bears more closely related to cats or dogs?)



# Are hyenas more closely related to cats or dogs?



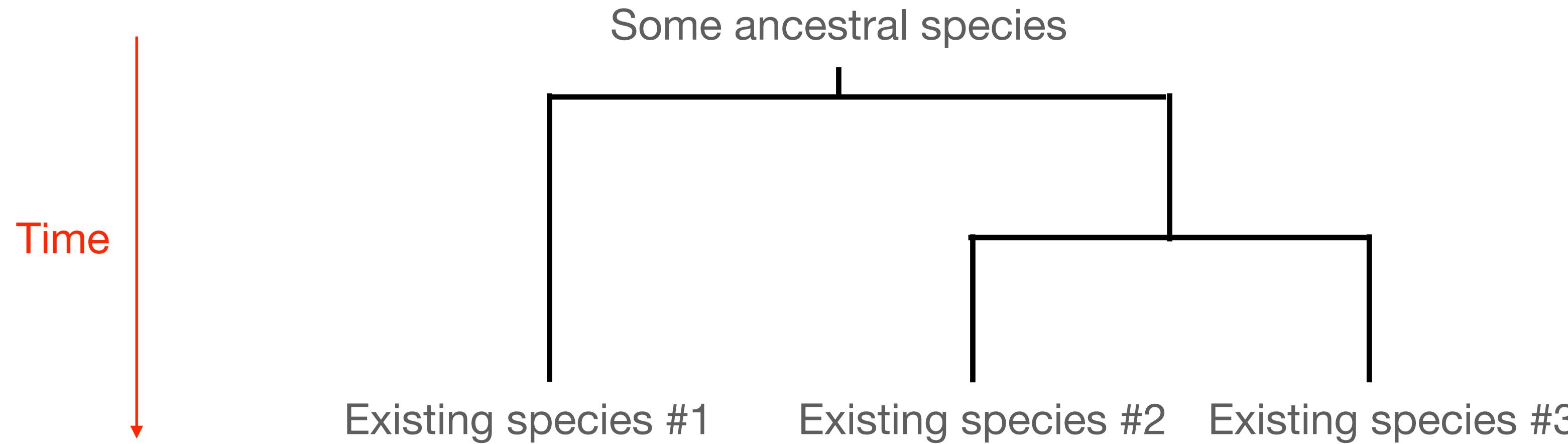
# Phylogenetic trees (aka Phylogenies, aka Evolutionary Trees) depict evolutionary relationships



Information conveyed includes:

- History of descent: which species came from which ancestors
- And relatedness: how closely related are different species

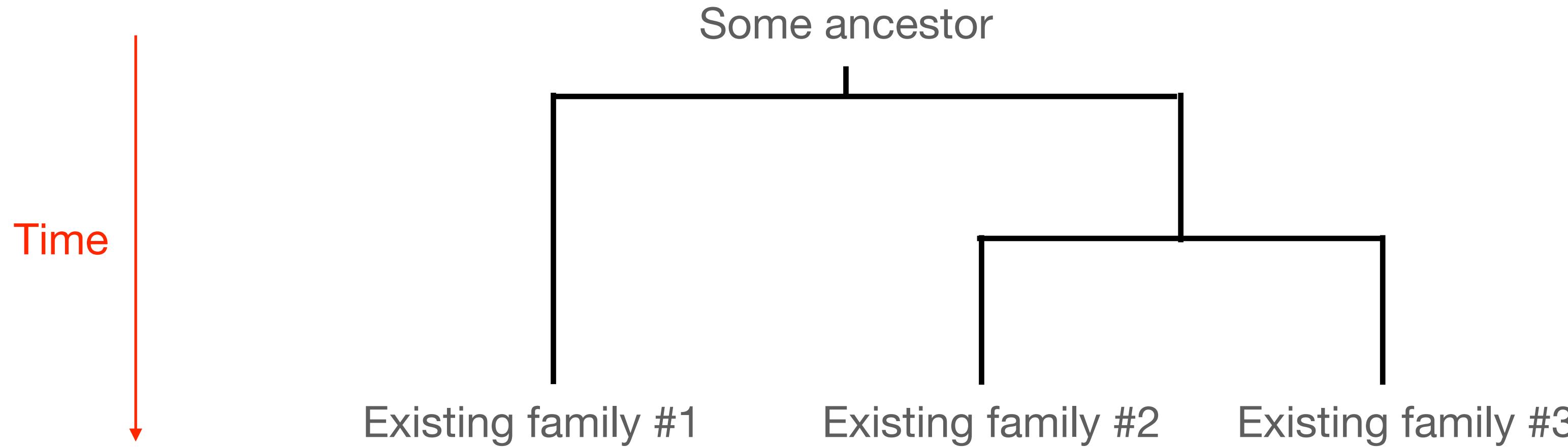
# Phylogenetic trees (aka Phylogenies, aka Evolutionary Trees) depict evolutionary relationships



We will address two issues:

- (1) how do you make a tree that is correct? (How would you know?)
- (2) how do you interpret an existing tree correctly?

# The tips in trees don't have to be species

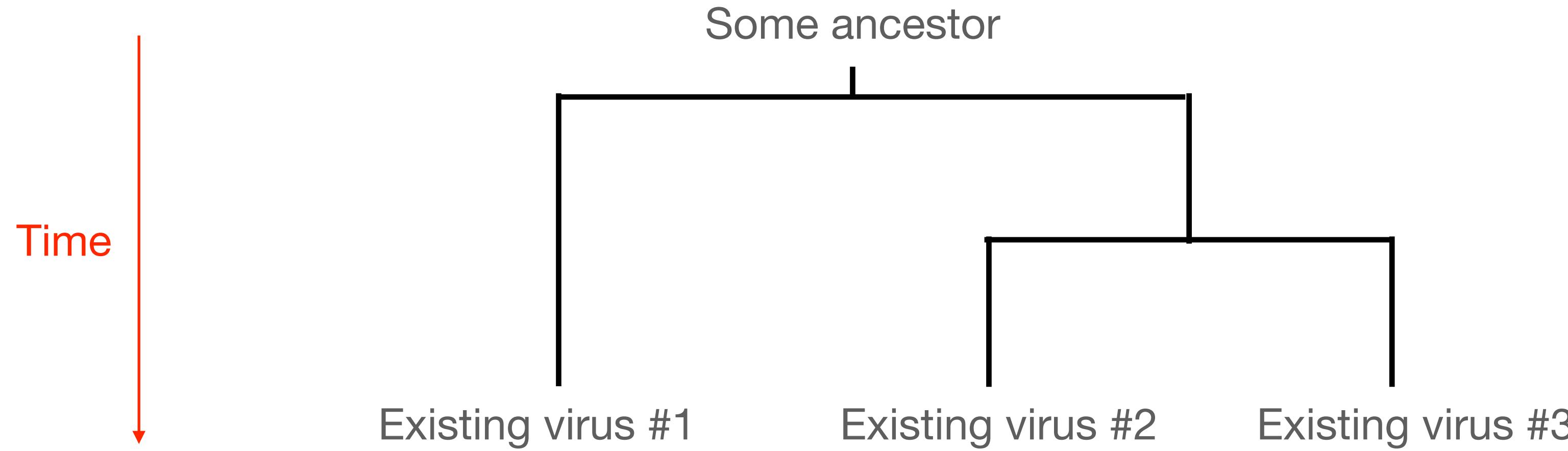


Tips can represent higher order taxa like genus or family

Tips can represent individuals within a species

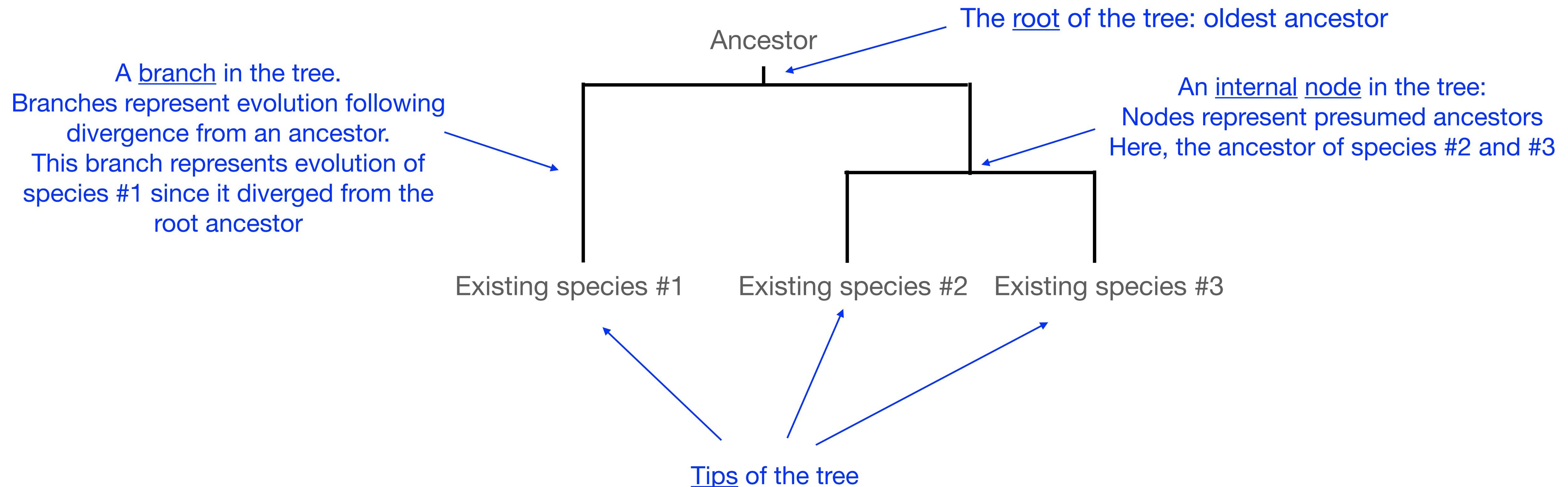
Tips can represent species that no longer exist (e.g. neanderthals)

# The tips in trees don't have to be species



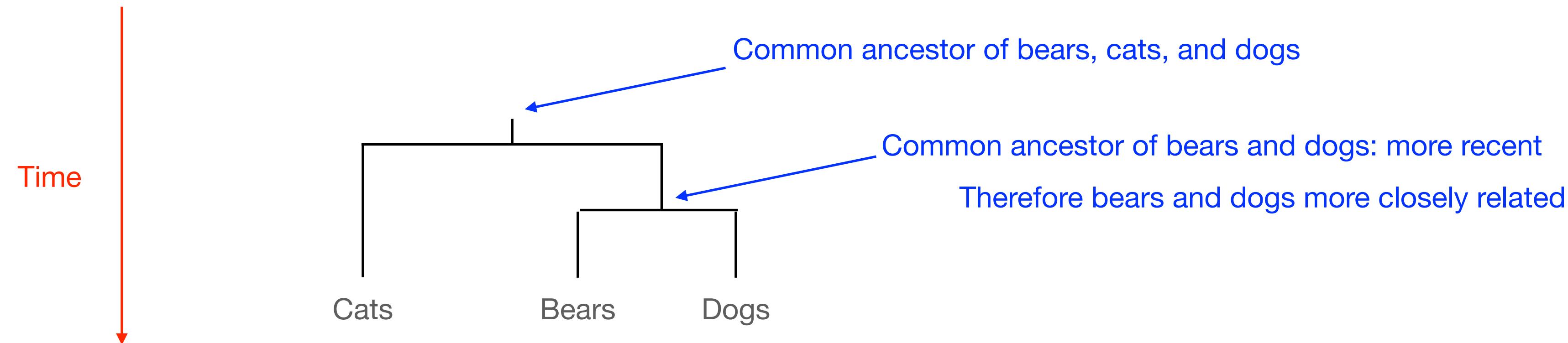
These 3 viruses could all belong to the same species

# Parts of a phylogenetic tree



# What does it mean for bears to be more closely related to dogs or cats?

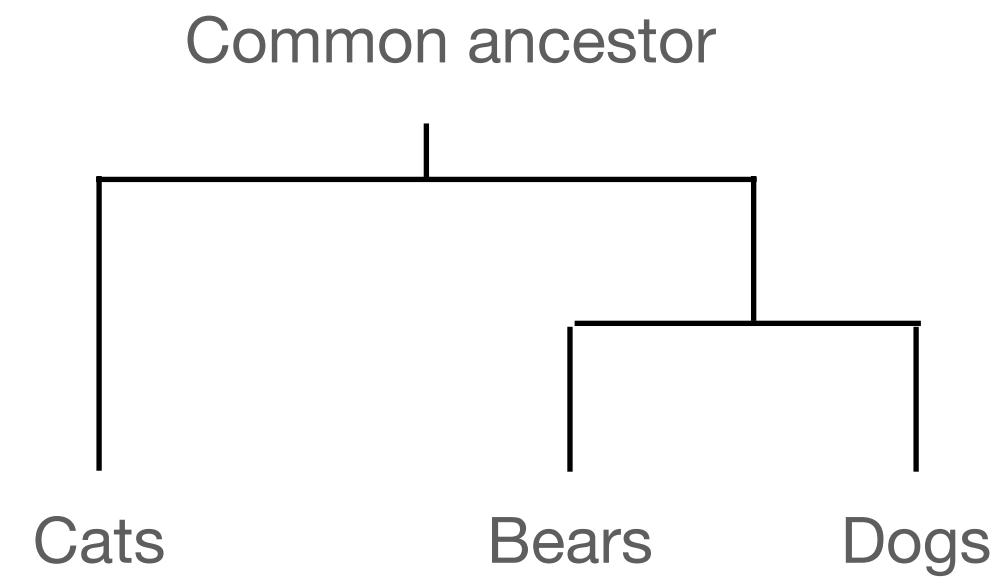
If this tree were correct, you would say that bears are more closely related to dogs because dogs and bears share a more recent common ancestor with each other, and a less recent common ancestor with cats



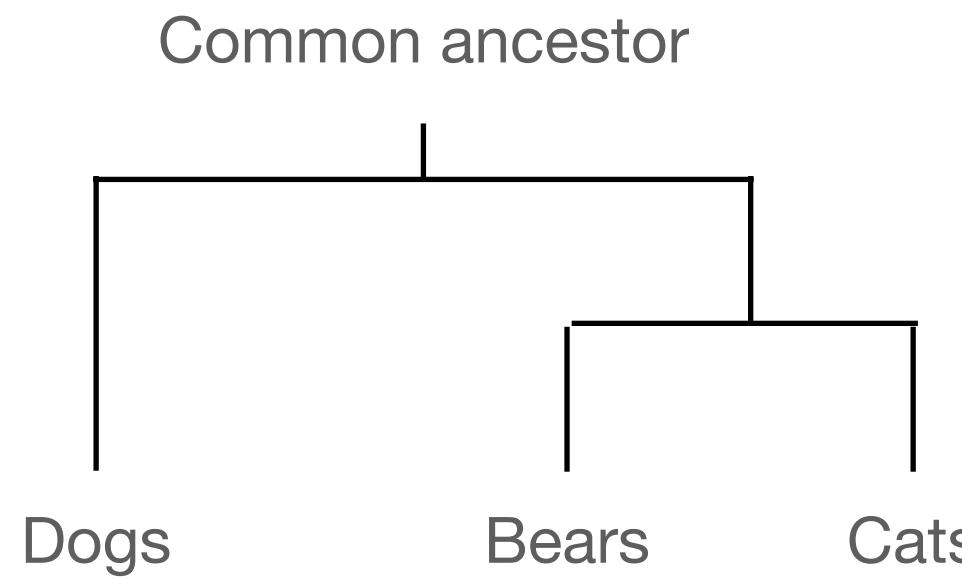
# Are bears more closely related to cats or dogs?

## Four possible trees: 4 possible answers

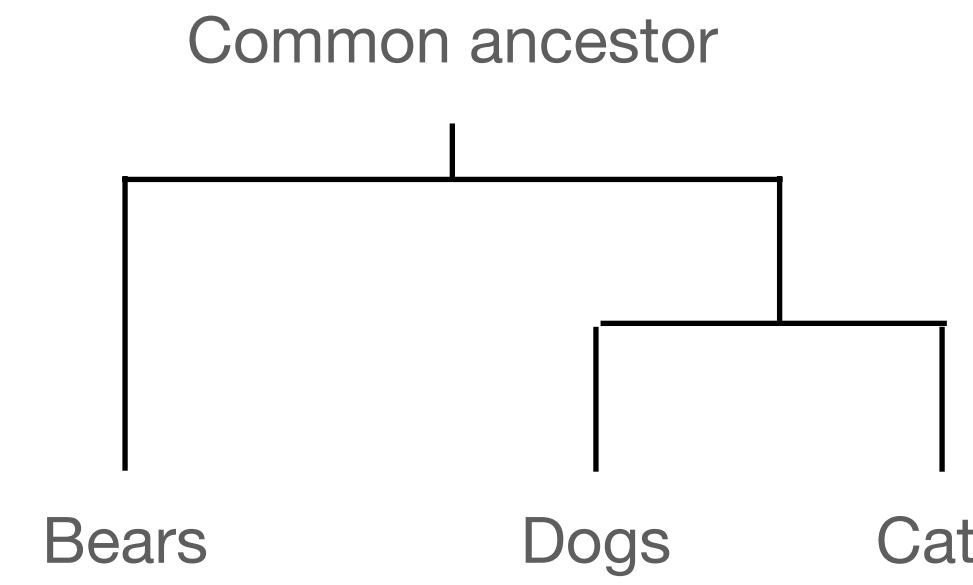
Tree 1



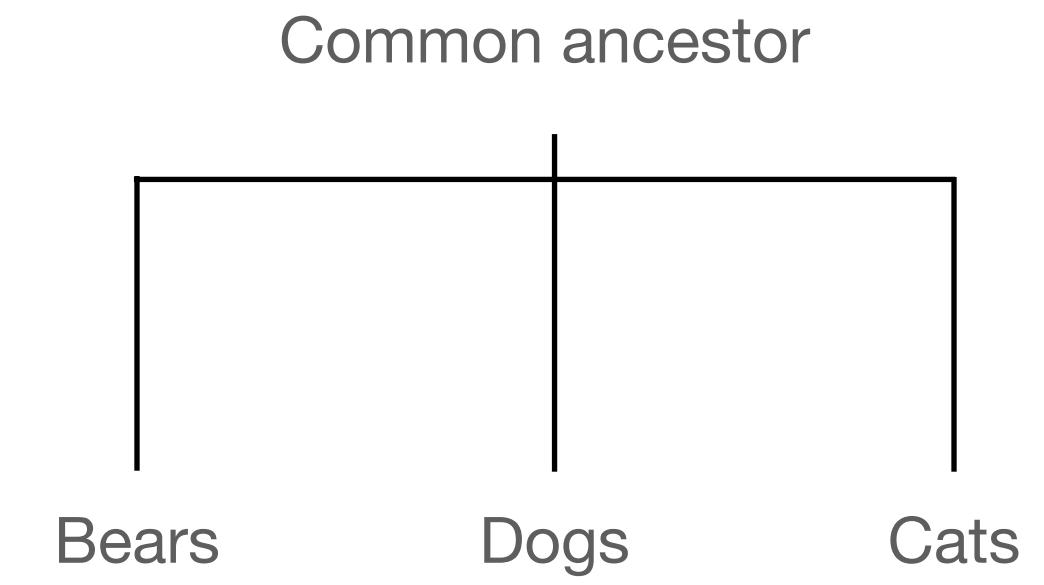
Tree 2



Tree 3



Tree 4

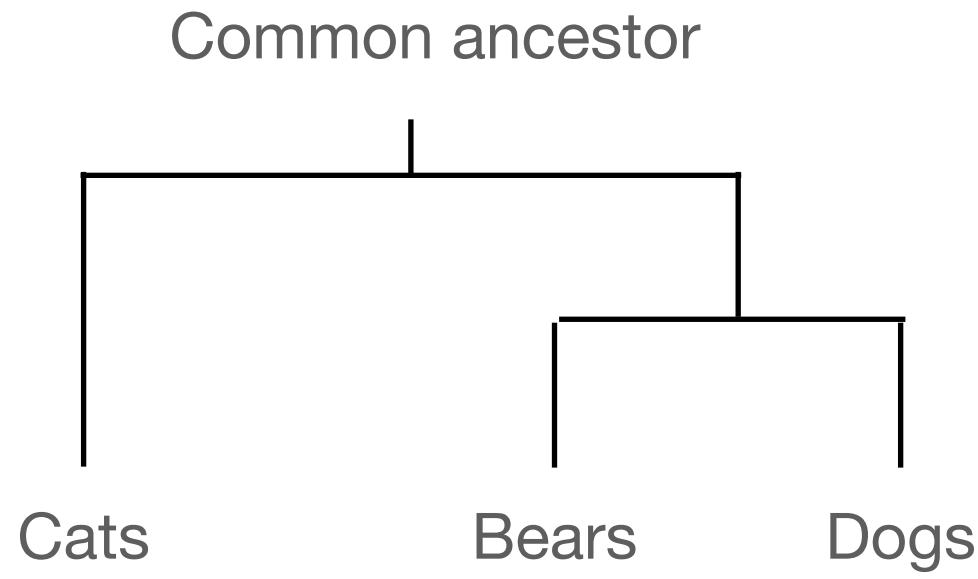


For each of these 4 trees, how would you answer the question?

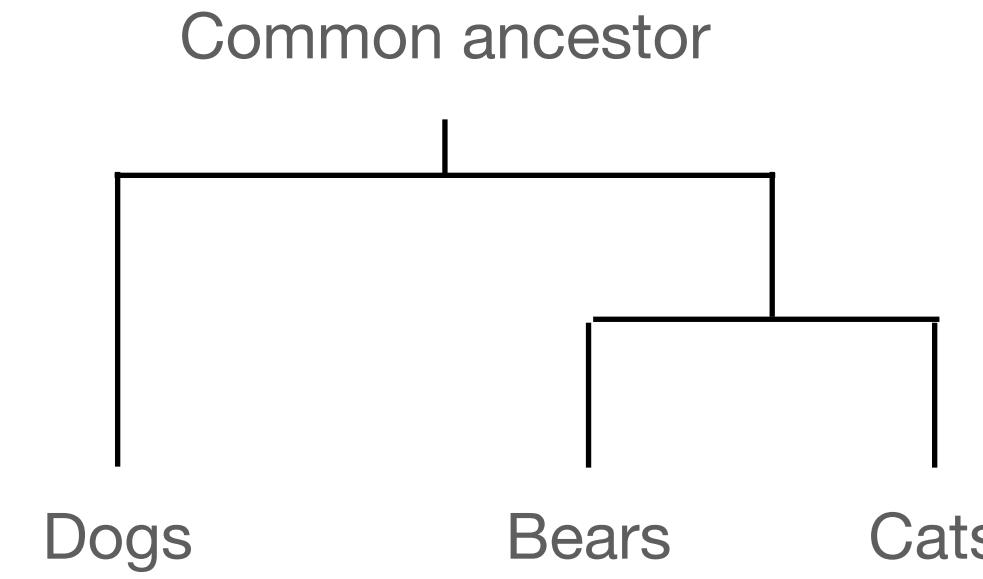
# Are bears (more closely related to) cats or dogs?

Four possible trees: 4 possible answers

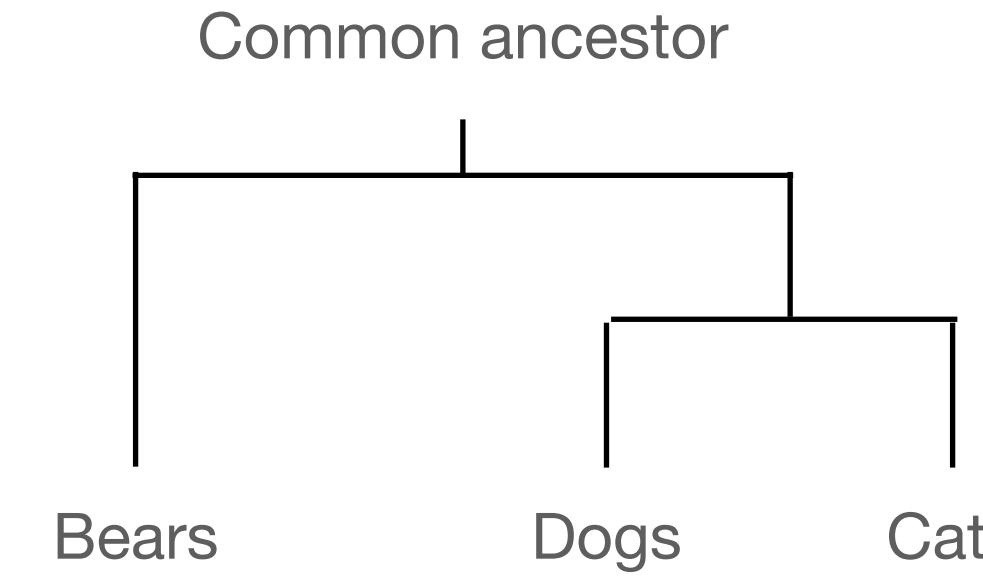
Bears are more closely related to dogs



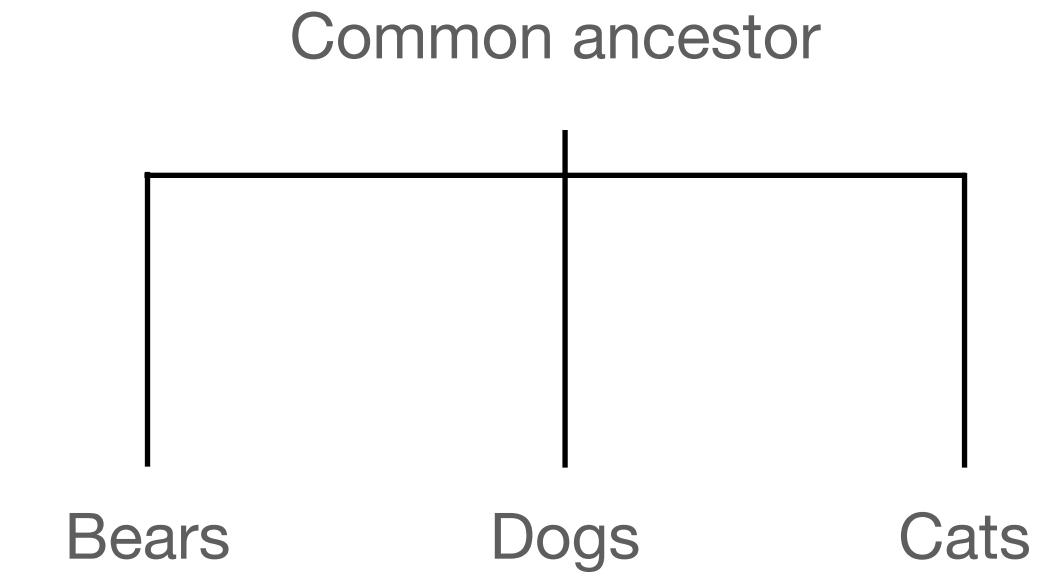
Bears are more closely related to cats



Bears are *equally* closely related to cats and dogs, and cats and dogs are more closely related to each other than to bears



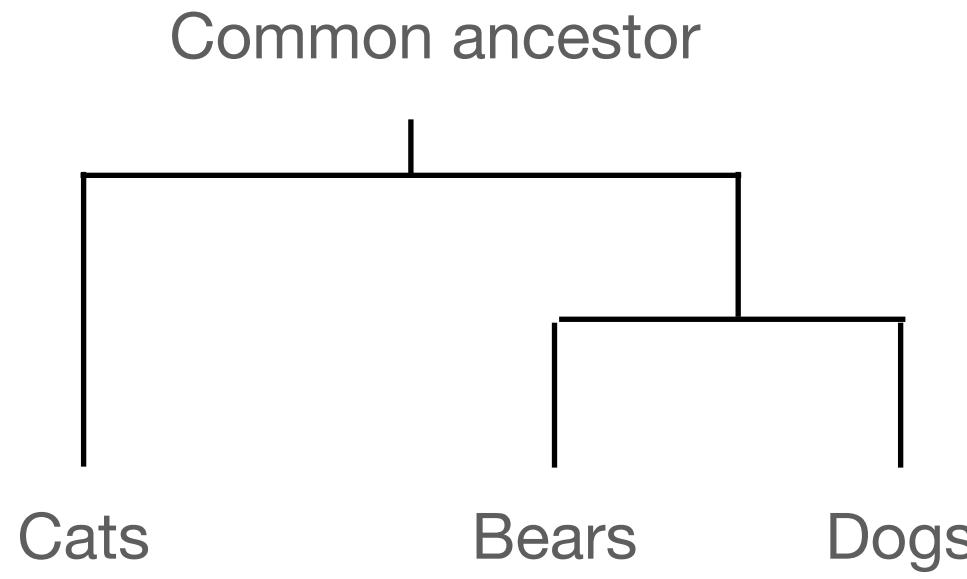
Bears, cats, and dogs, are all equally closely related



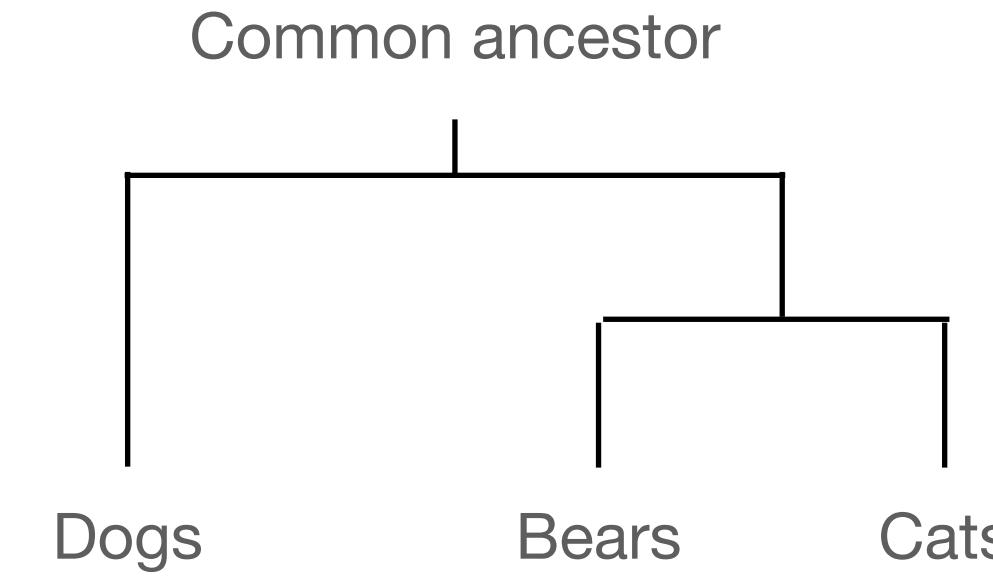
# Are bears (more closely related to) cats or dogs?

Four possible trees: 4 possible answers

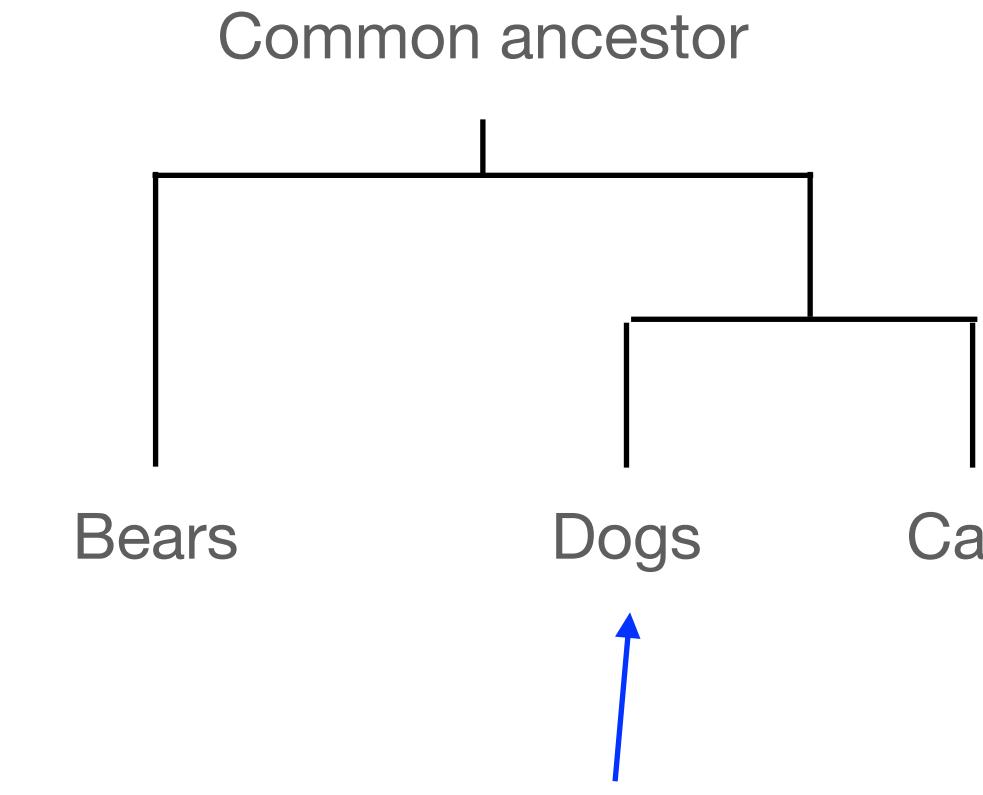
Bears are more closely related to dogs



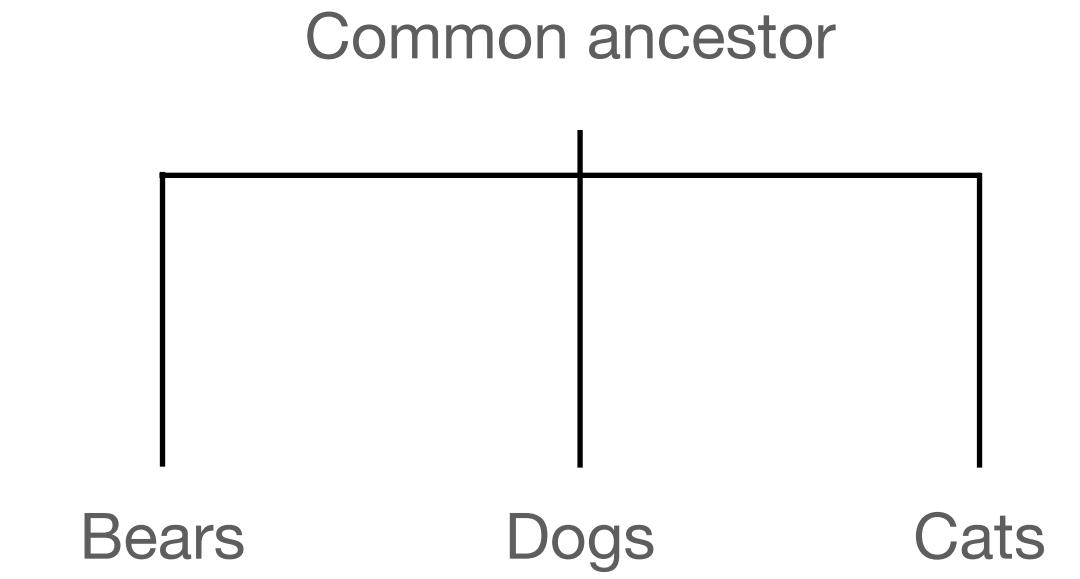
Bears are more closely related to cats



Bears are equally closely related to cats and dogs, and cats and dogs are more closely related to each other than to bears



Bears, cats, and dogs, are all equally closely related



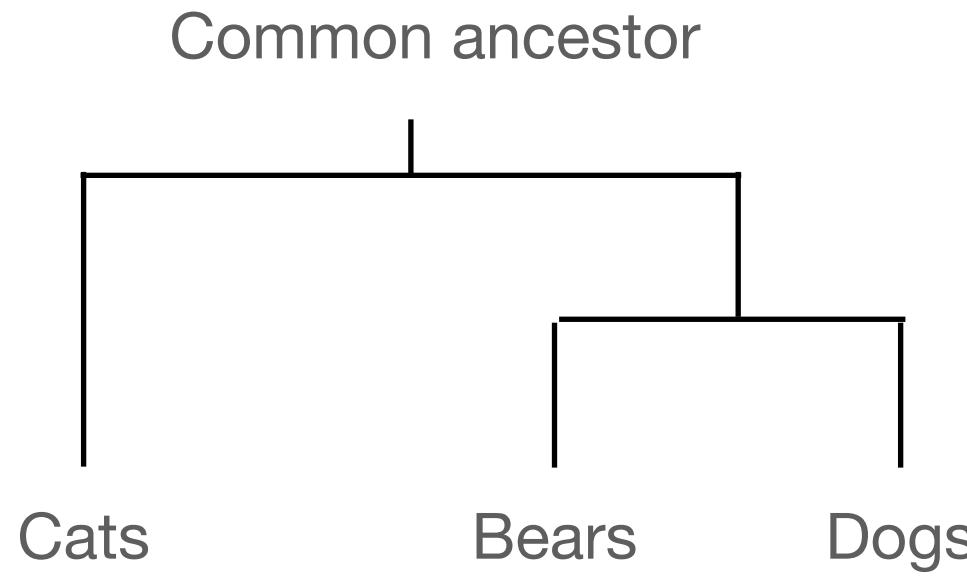
There is no reason that Dogs should be drawn on the left and Cats on the right here.

This is like saying that you are equally related to two cousins who are siblings of each other

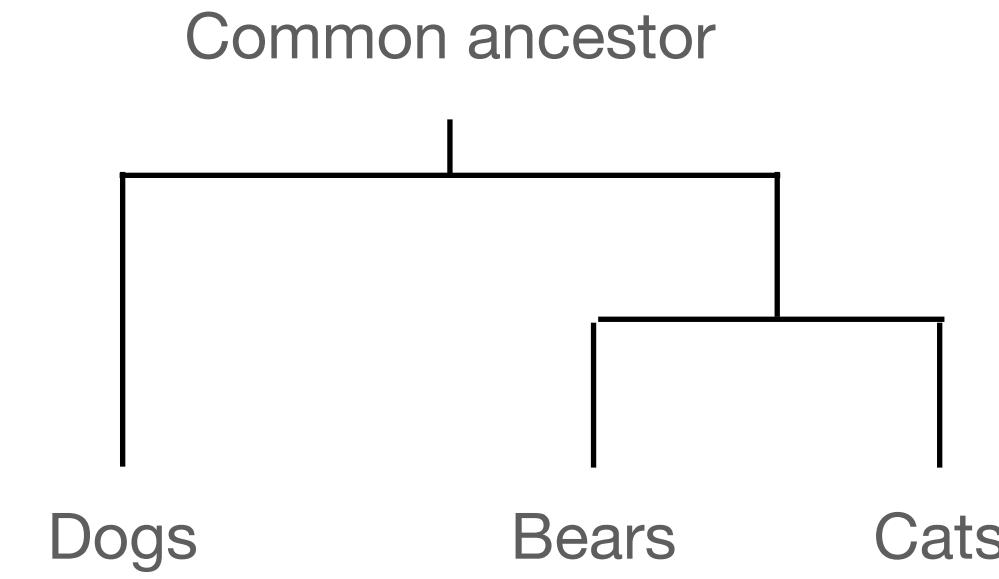
# Are bears (more closely related to) cats or dogs?

Four possible trees: 4 possible answers

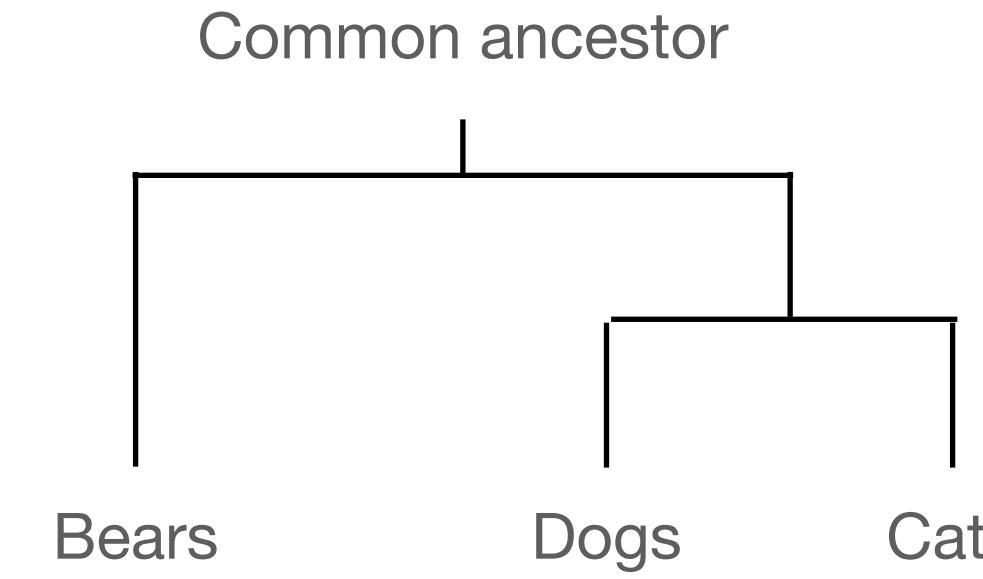
Bears are more closely related to dogs



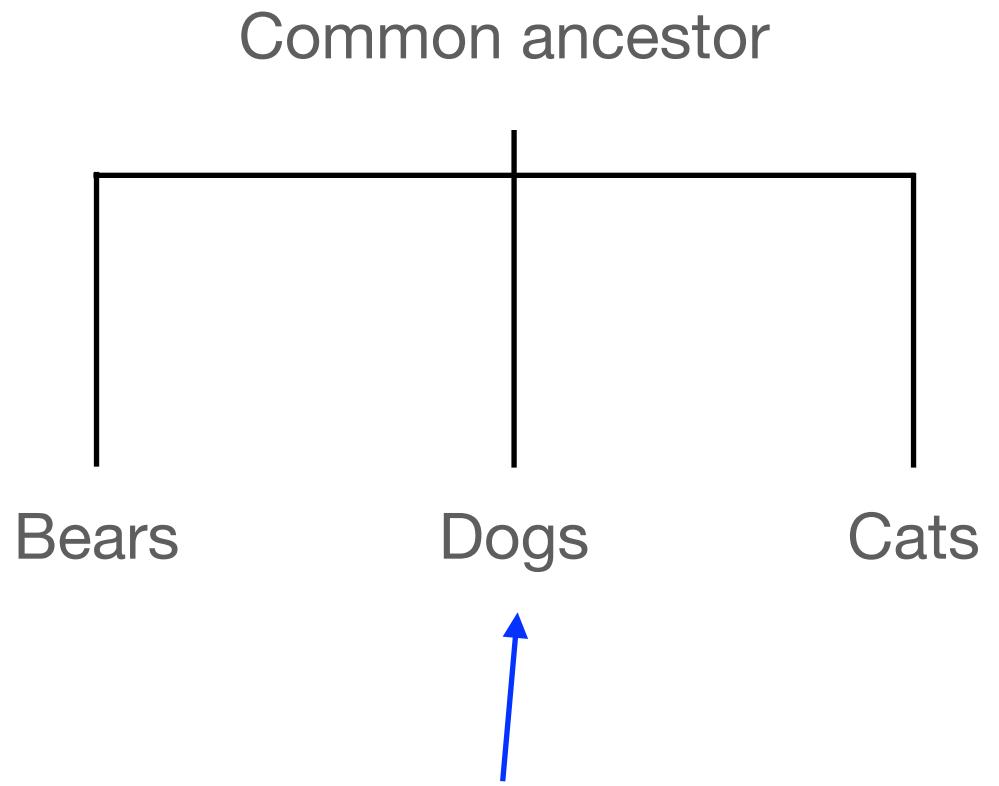
Bears are more closely related to cats



Bears are *equally* closely related to cats and dogs, and cats and dogs are more closely related to each other than to bears



Bears, cats, and dogs, are all equally closely related



This is like saying three cousins, none of which are siblings, are equally related

# Are bears more closely related to dogs or cats?

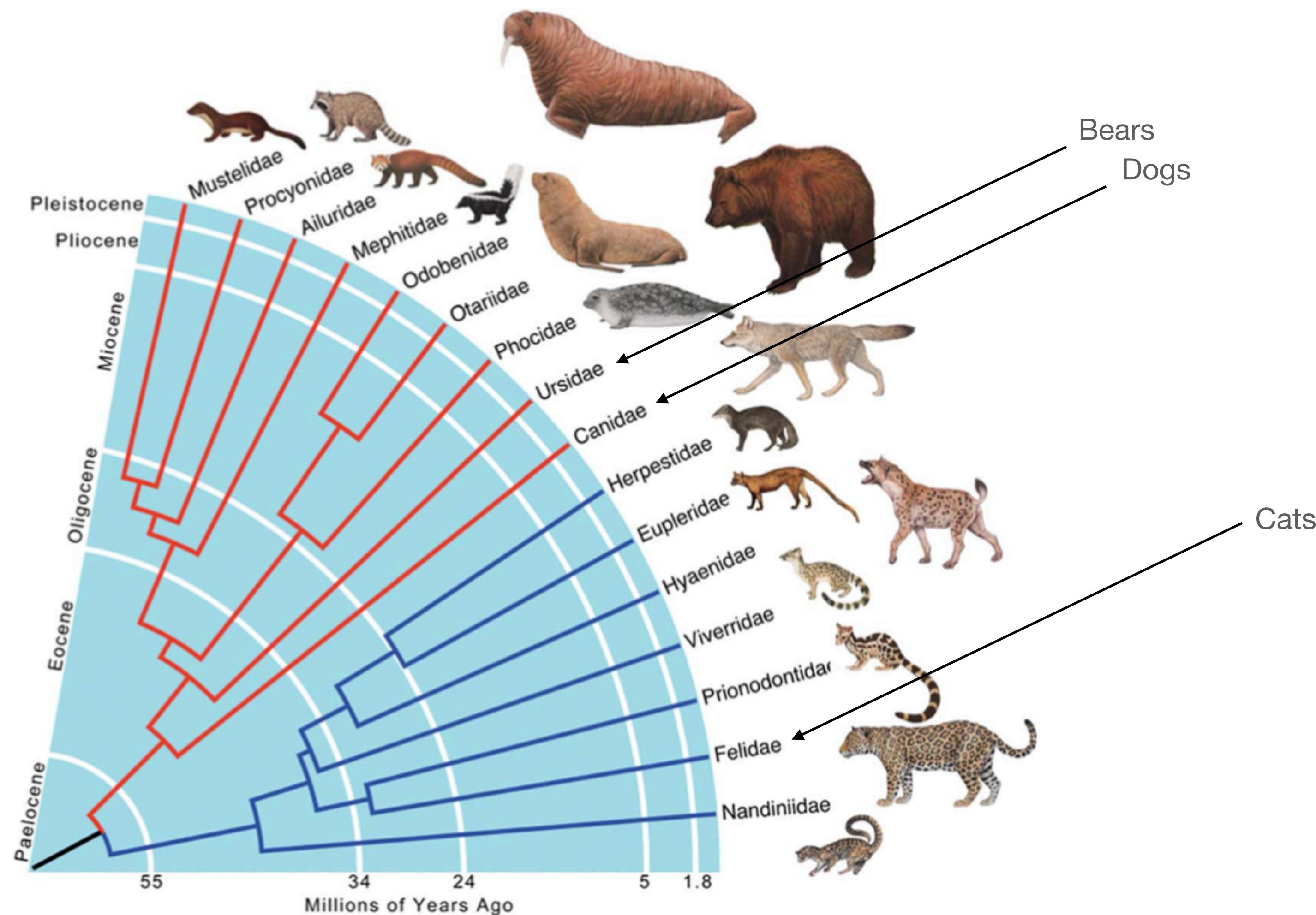


Fig. 1. Time-calibrated phylogeny of the order Carnivora at the family level based on multiple nuclear gene sequences, with millions of years on the horizontal axis and Cenozoic epochs on the near vertical axis. Caniformia shown in red, Feliformia shown in blue. All but the following families are represented in this study: Ailuridae, Odobenidae, Otariidae, Phocidae, and Eupleridae. Figure from Van Valkenburgh and Wayne, 2010.

# Bears are more closely related to dogs than to cats

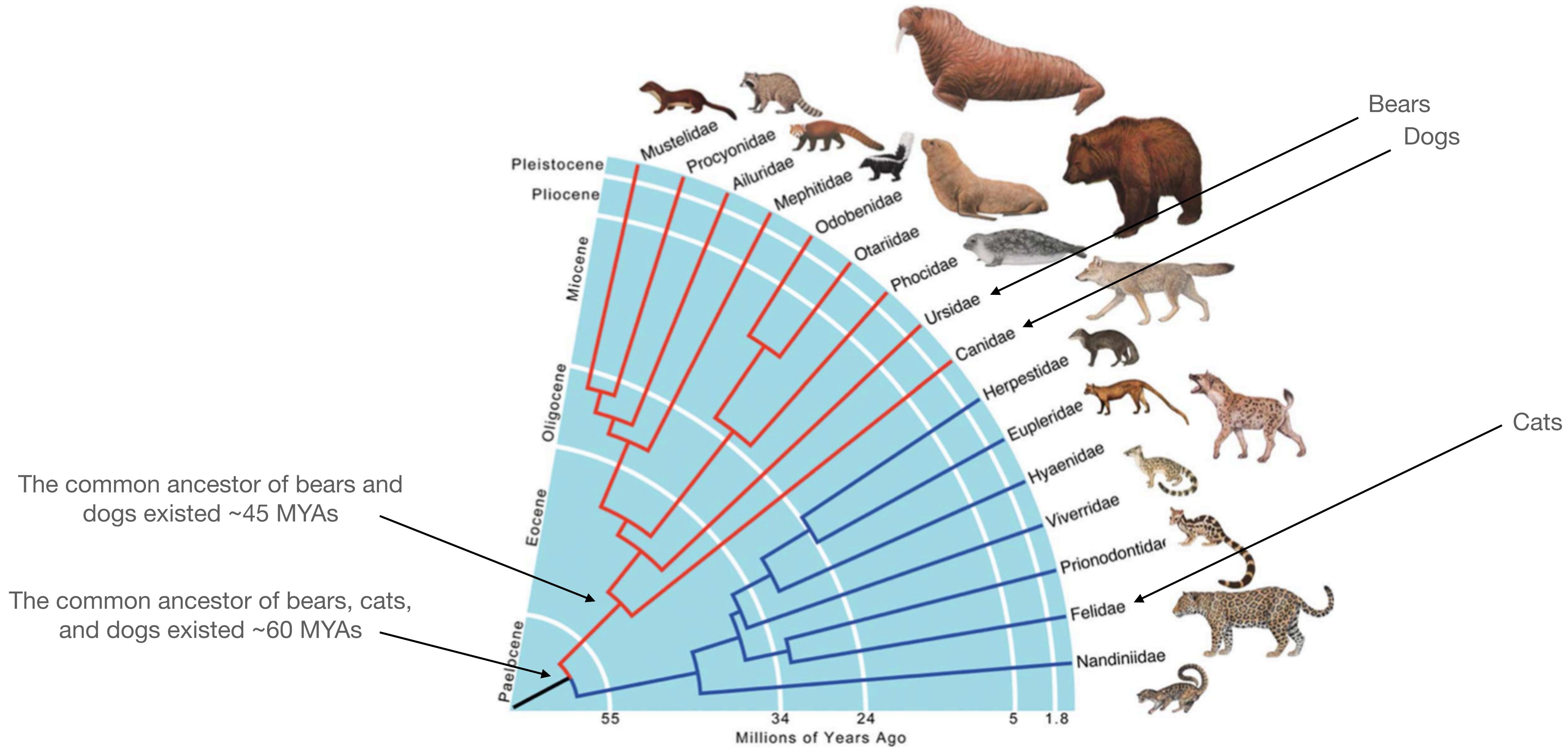


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# Are bears more closely related to skunks or dogs?

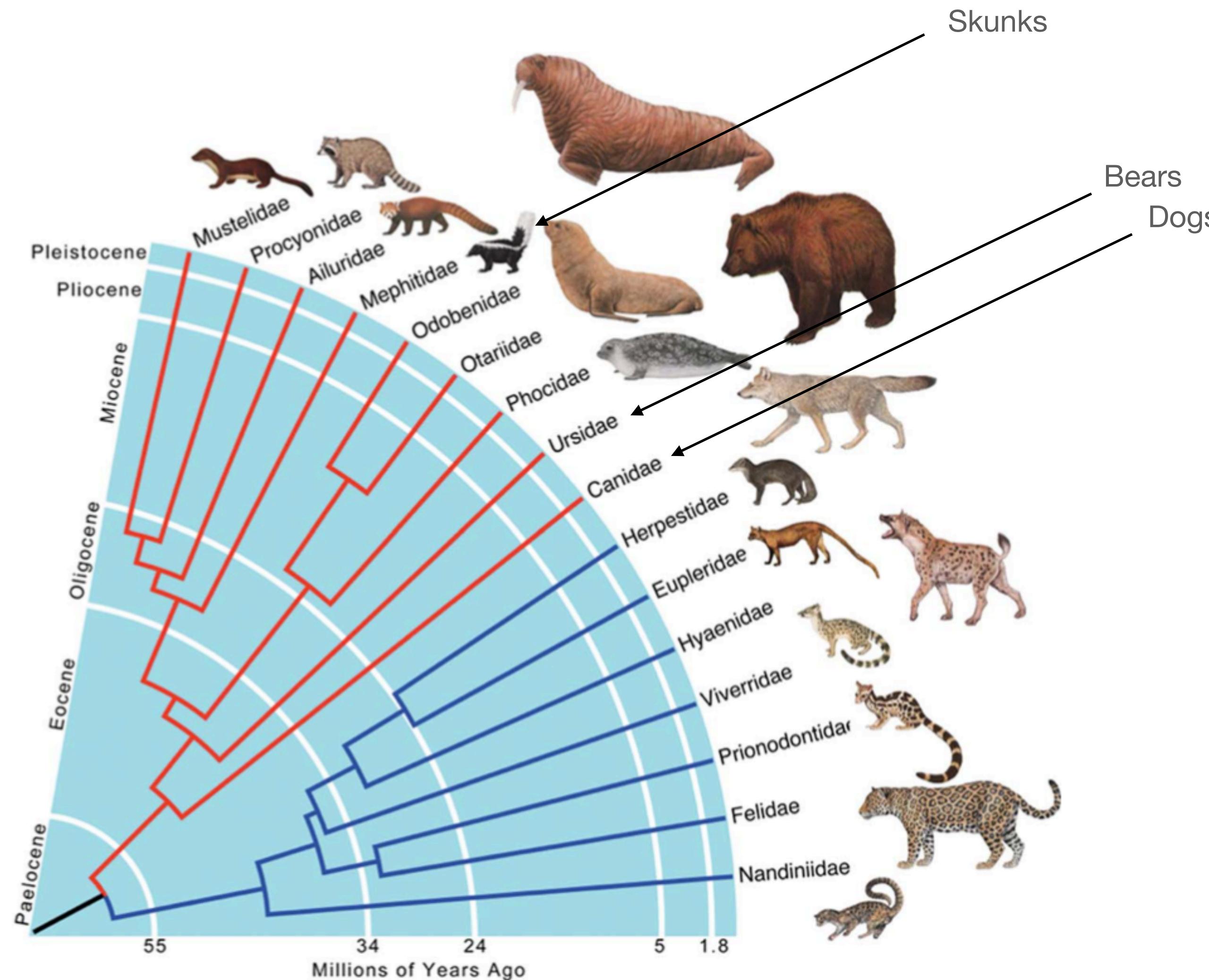
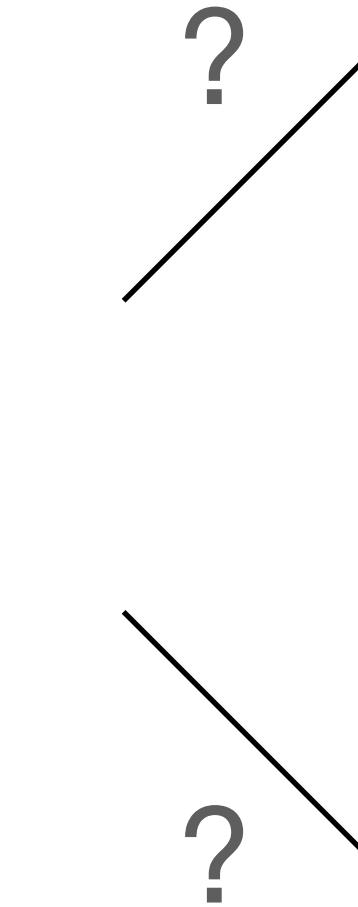


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# Are hyenas more closely related to cats or dogs?



# Hyenas share a more recent common ancestor with cats than dogs (Are more closely related to cats)

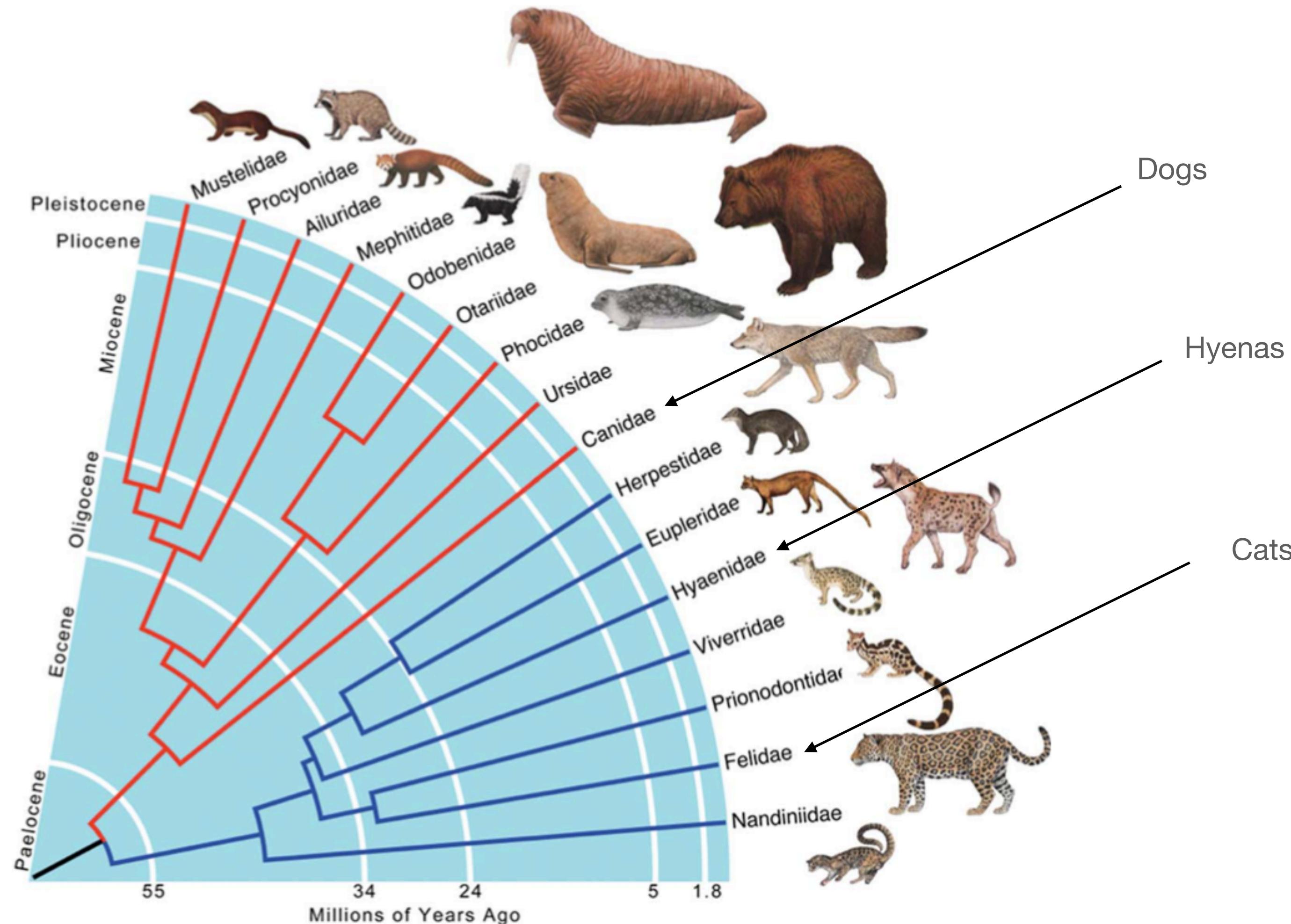


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Many following examples taken from this paper: a great resource

Evo Edu Outreach (2008) 1:121–137  
DOI 10.1007/s12052-008-0035-x

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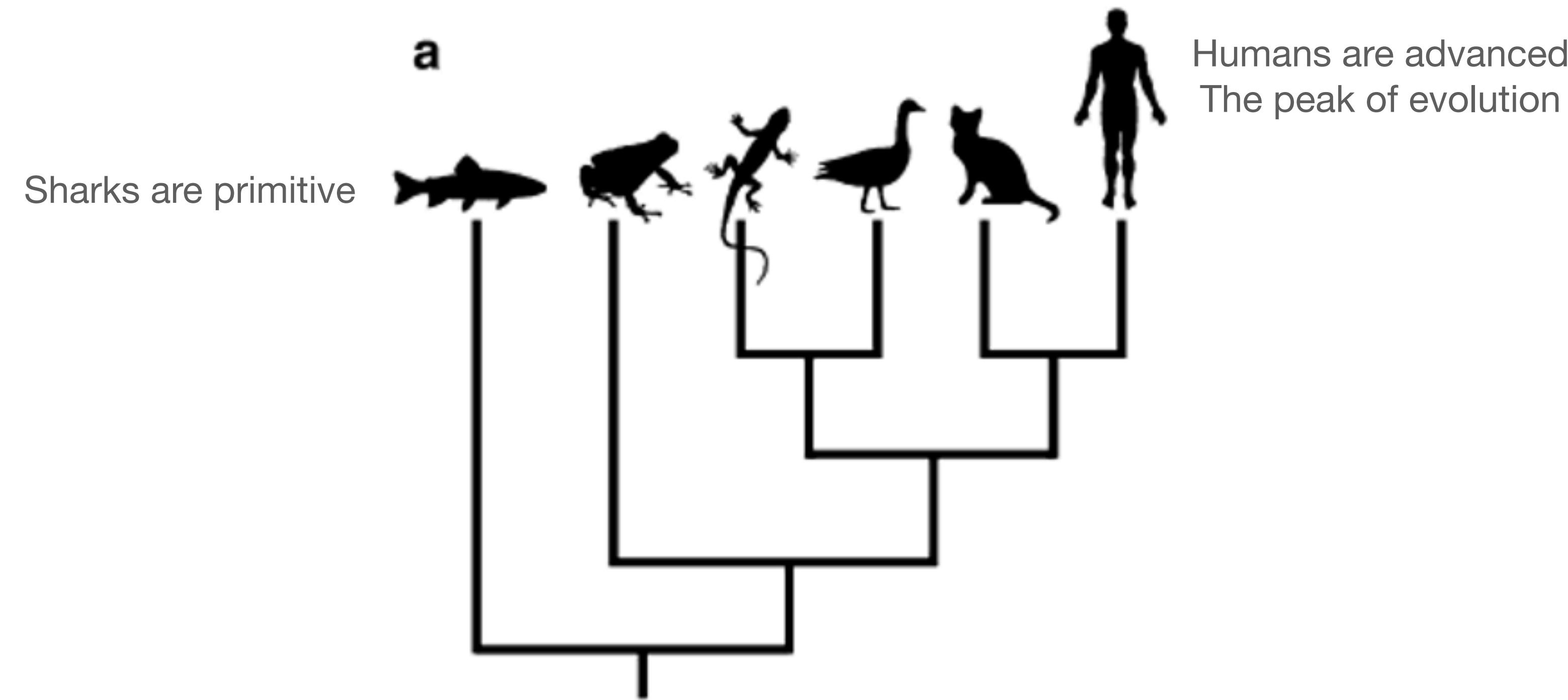
ORIGINAL SCIENCE/EVOLUTION REVIEW

## **Understanding Evolutionary Trees**

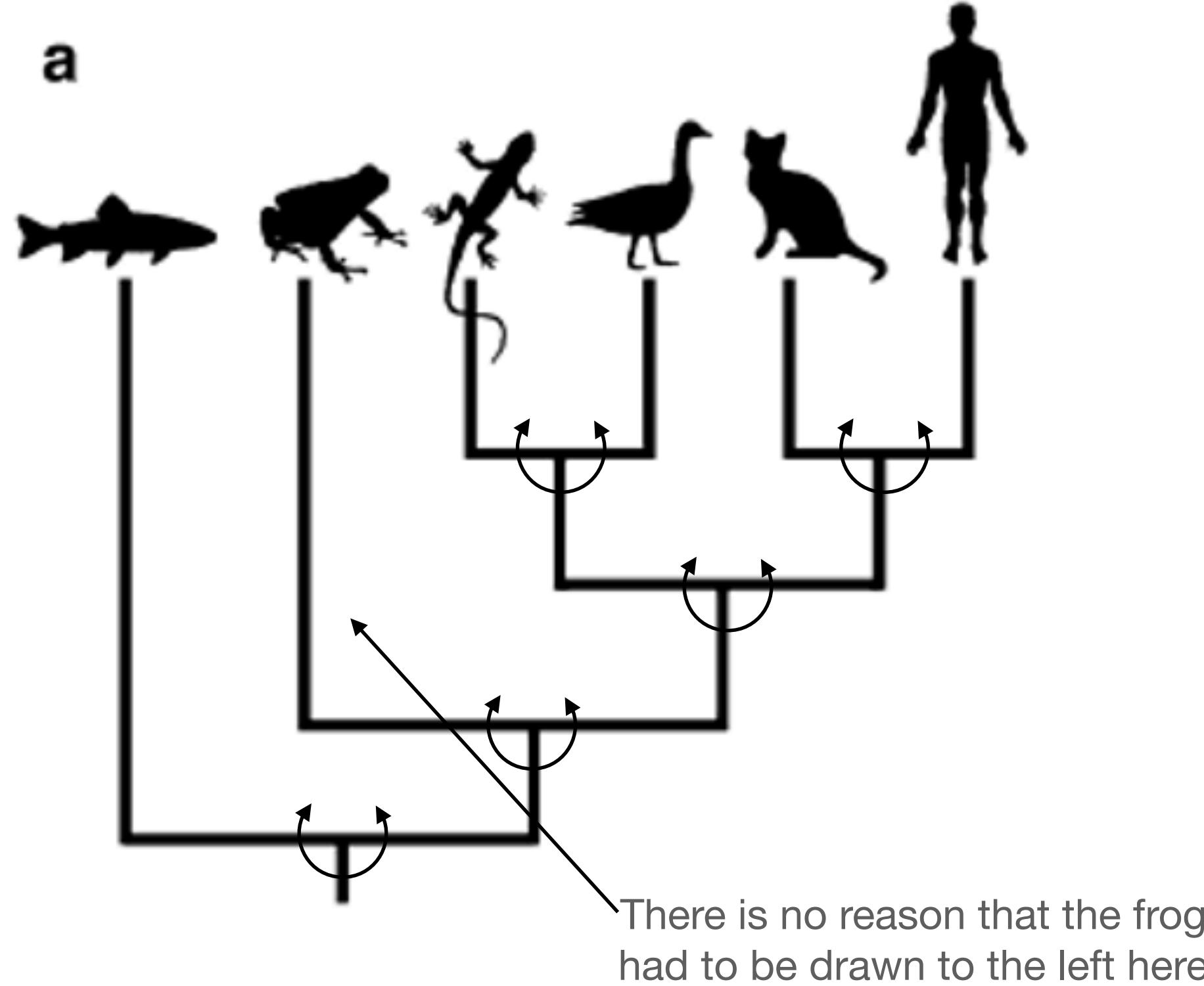
**T. Ryan Gregory**

There are several reasons people have difficulty interpreting trees

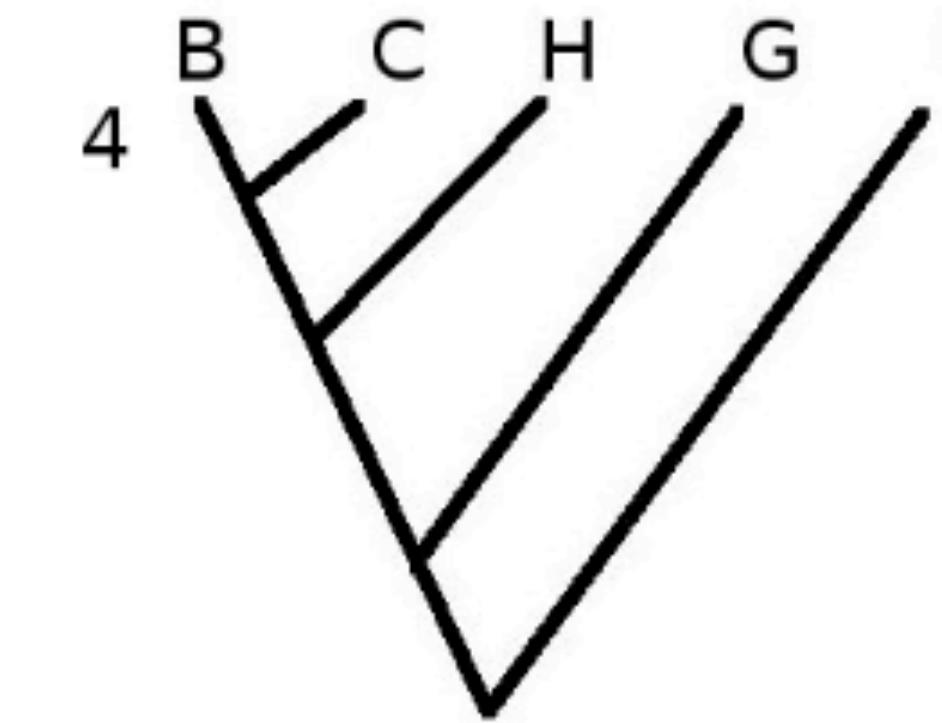
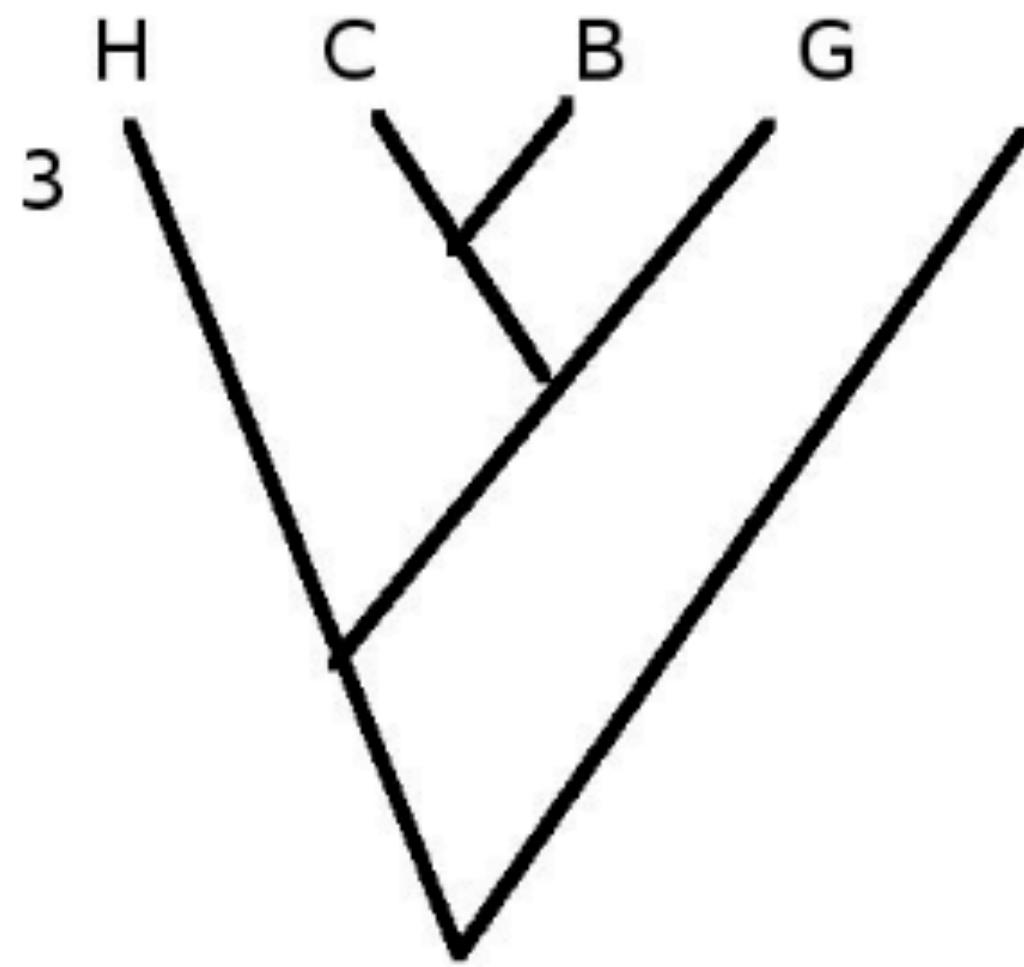
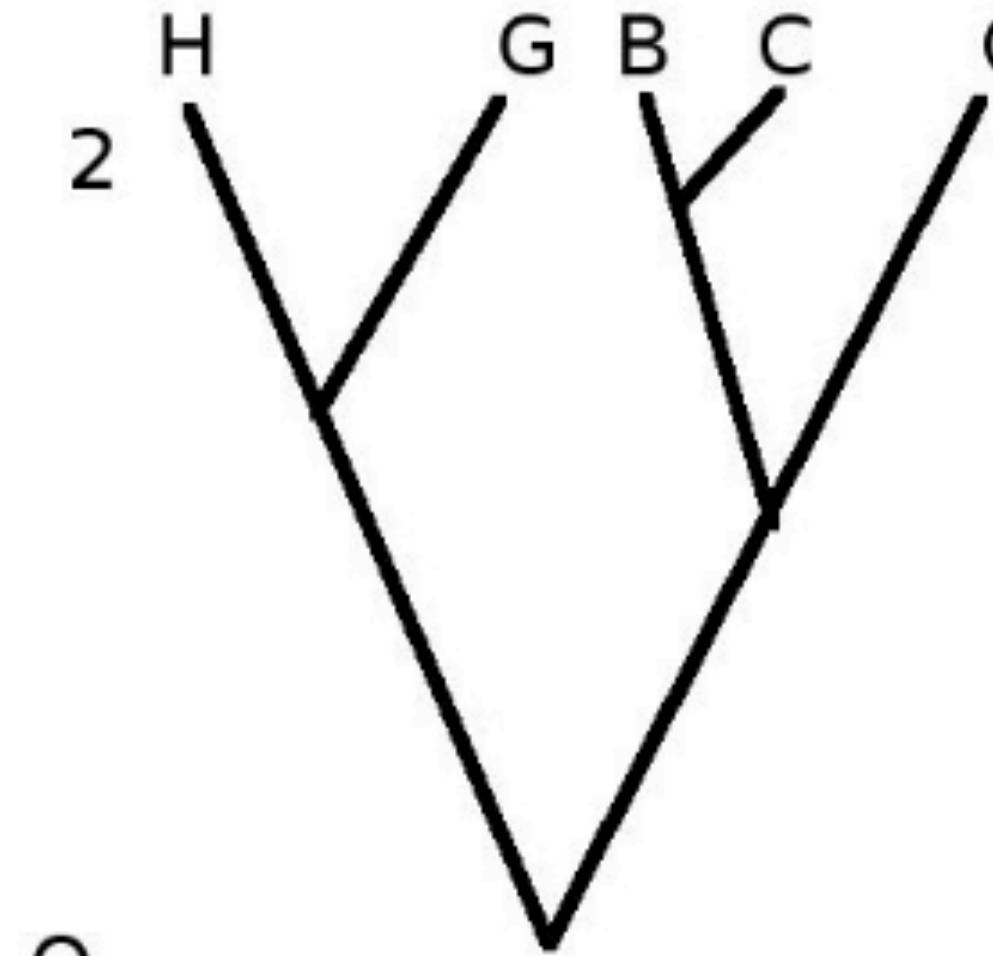
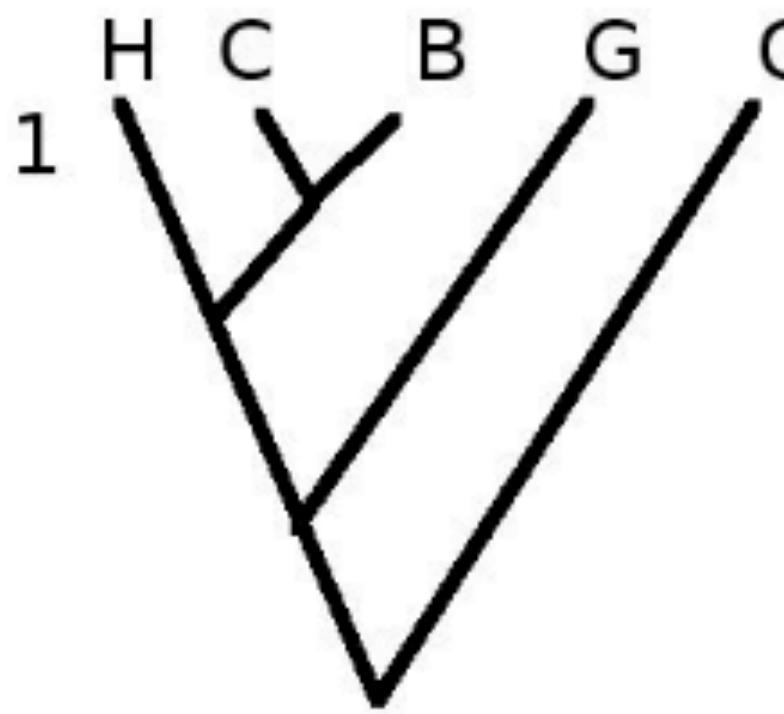
One issue is that people sometimes impose *implicit value judgements* on their interpretation of trees



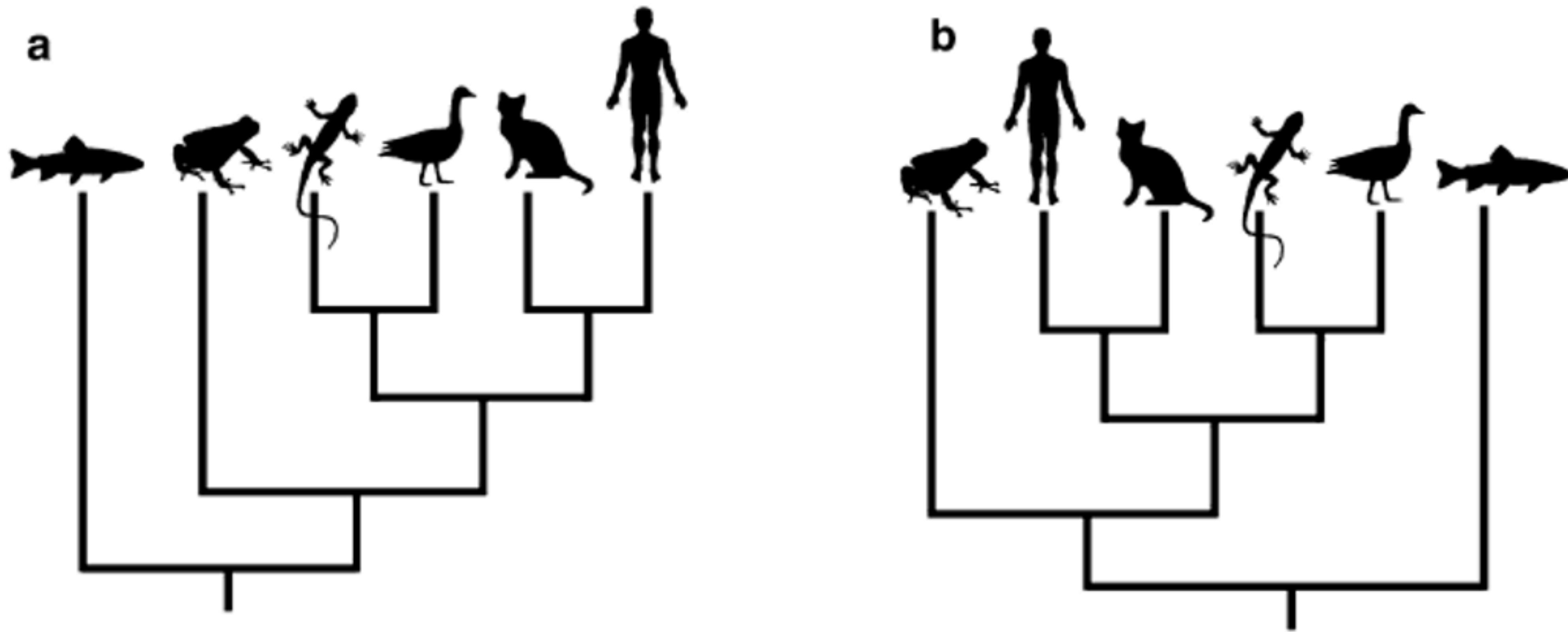
# Trees are like mobiles: rotations around internal nodes are allowed



Two of these trees are the same (except for branch lengths). Which two?



These are equally valid presentations of this tree

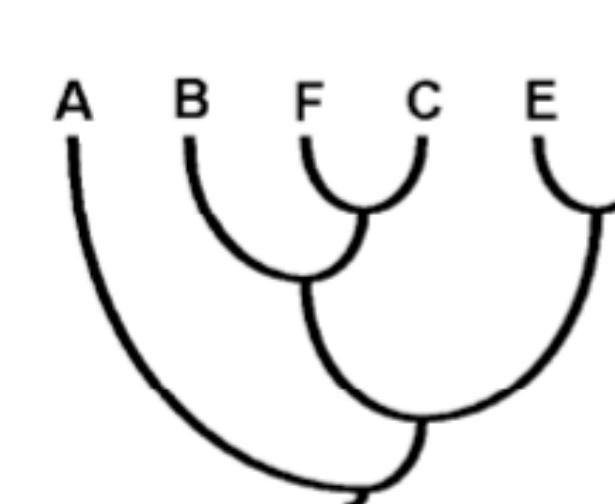
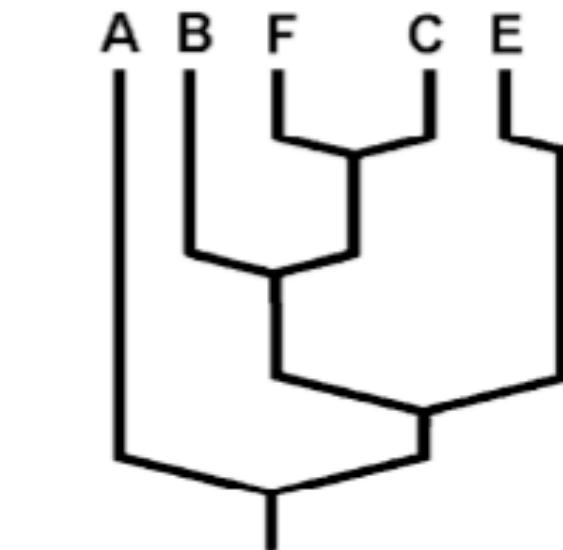
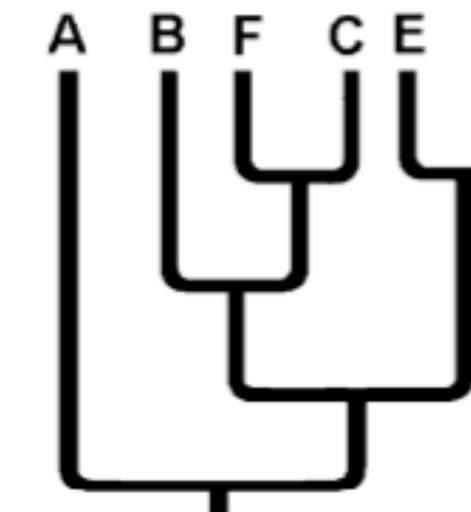
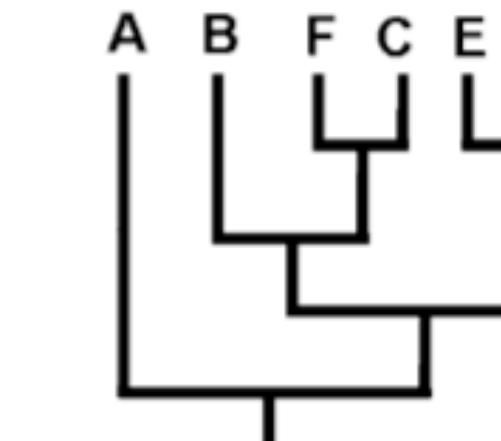
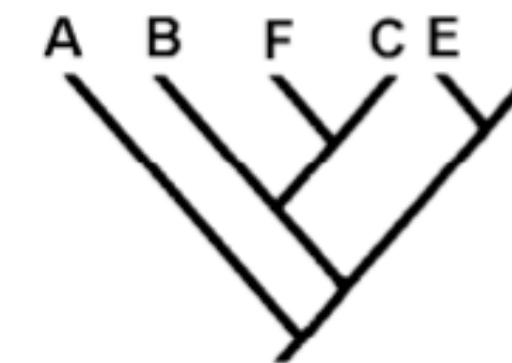


*It is a good mental exercise to do this when interpreting trees*

# Some tree representations are harder to interpret than others

These are all legitimate ways of representing the same tree

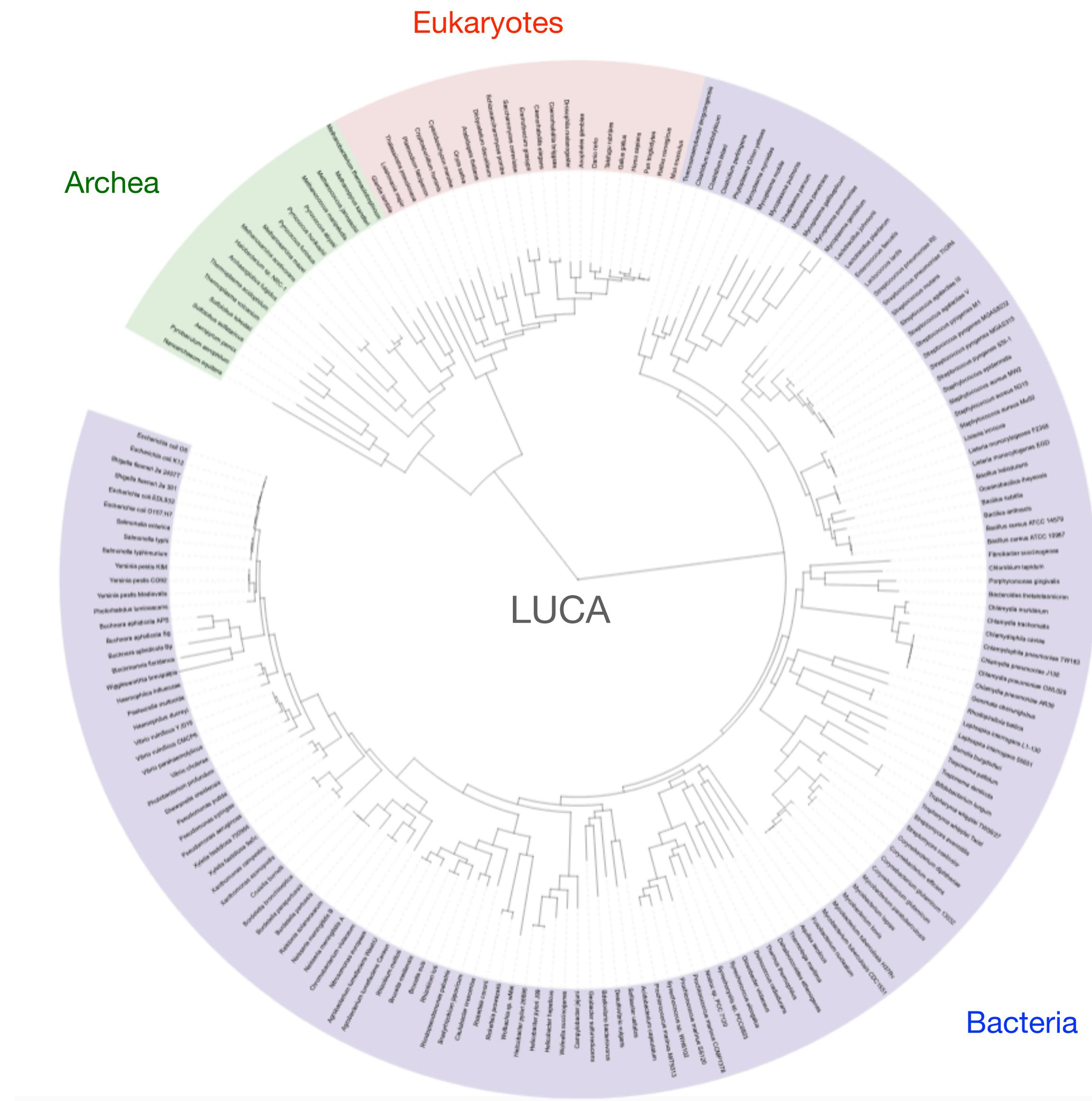
This tree looks like it has an evolutionary “main line” to species D



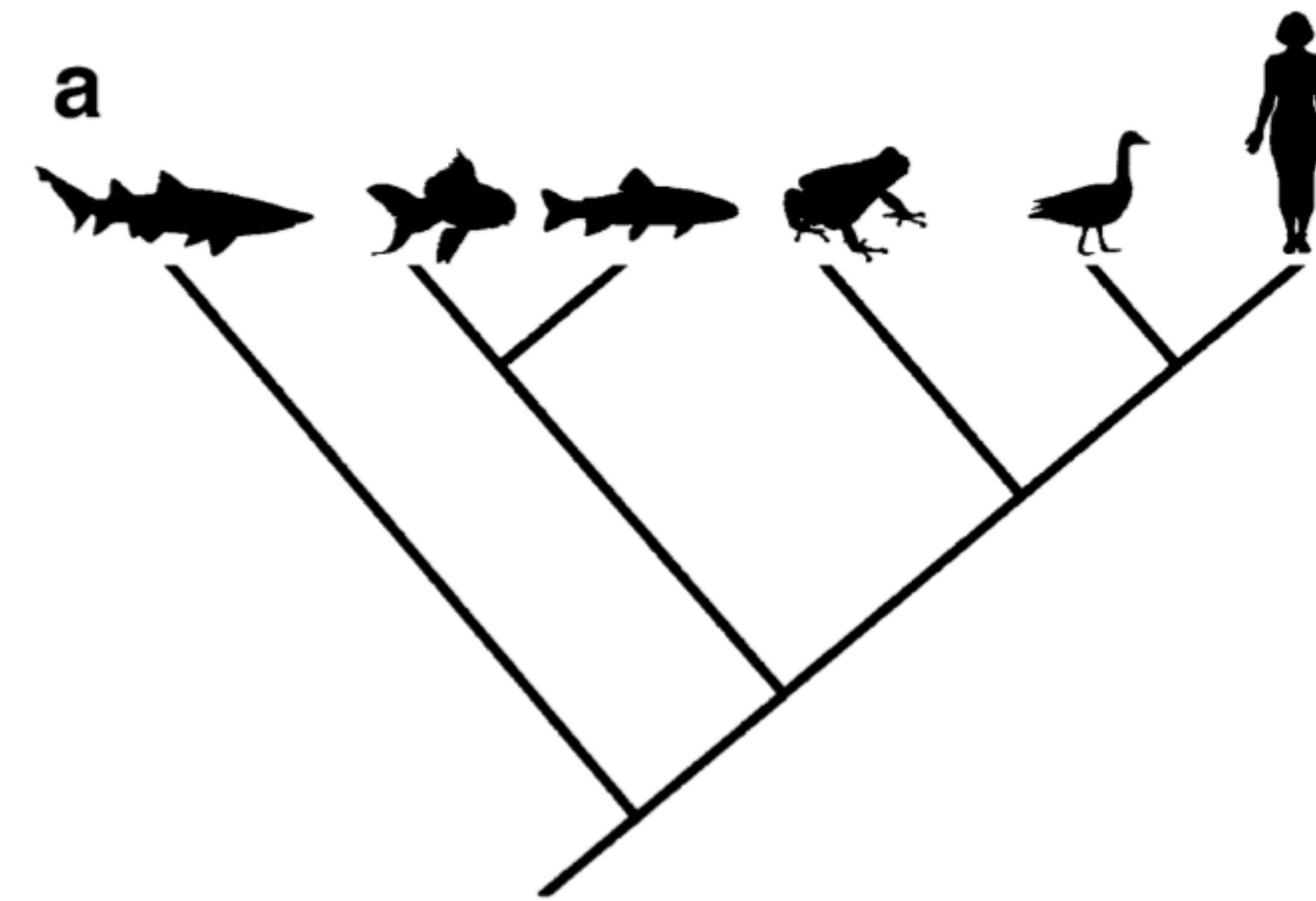
Trees like this are just kind of hard to interpret

**Fig. 4** Evolutionary trees can be presented in a variety of ways. This

# This tree of life uses a radial layout.

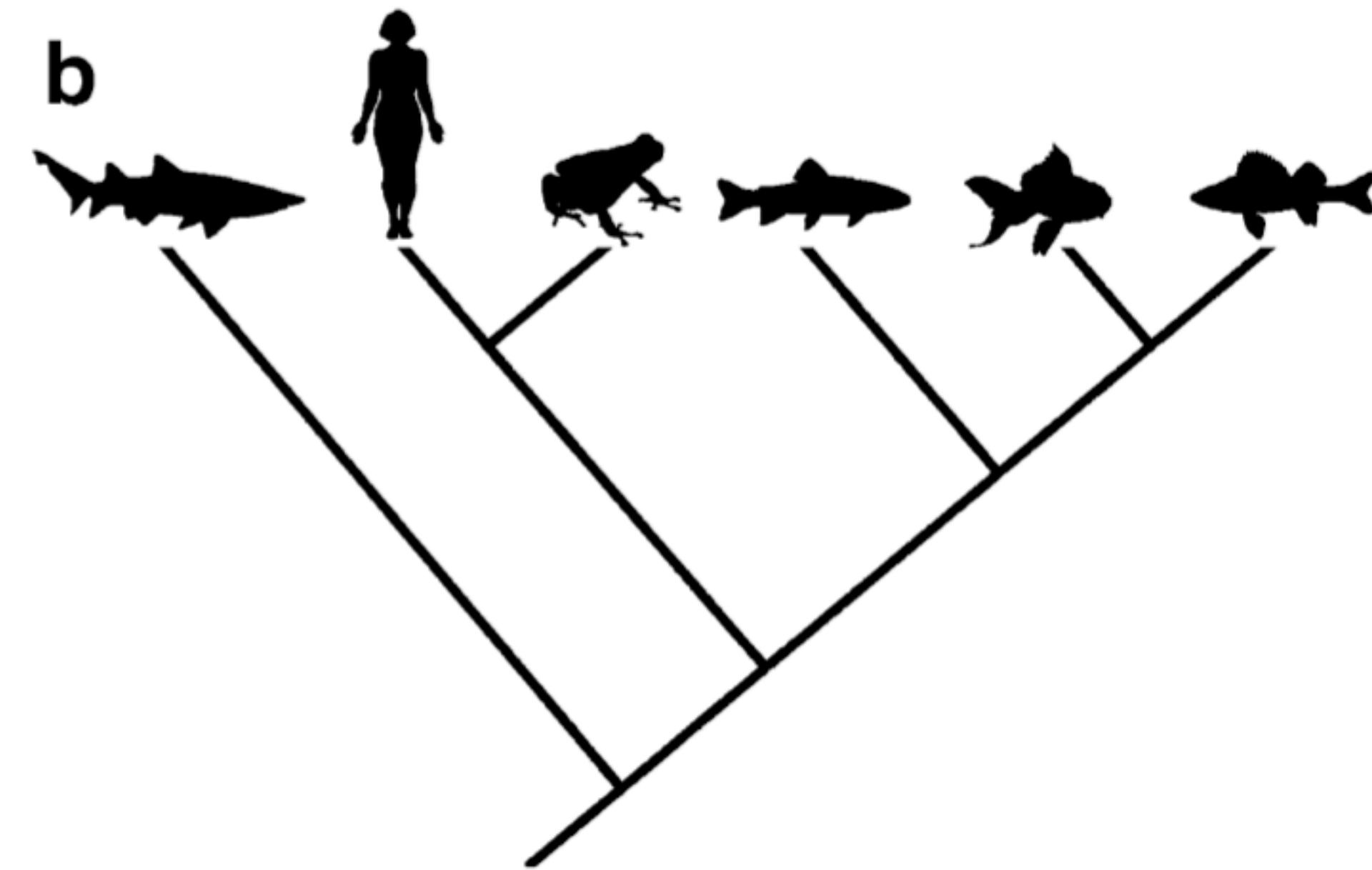
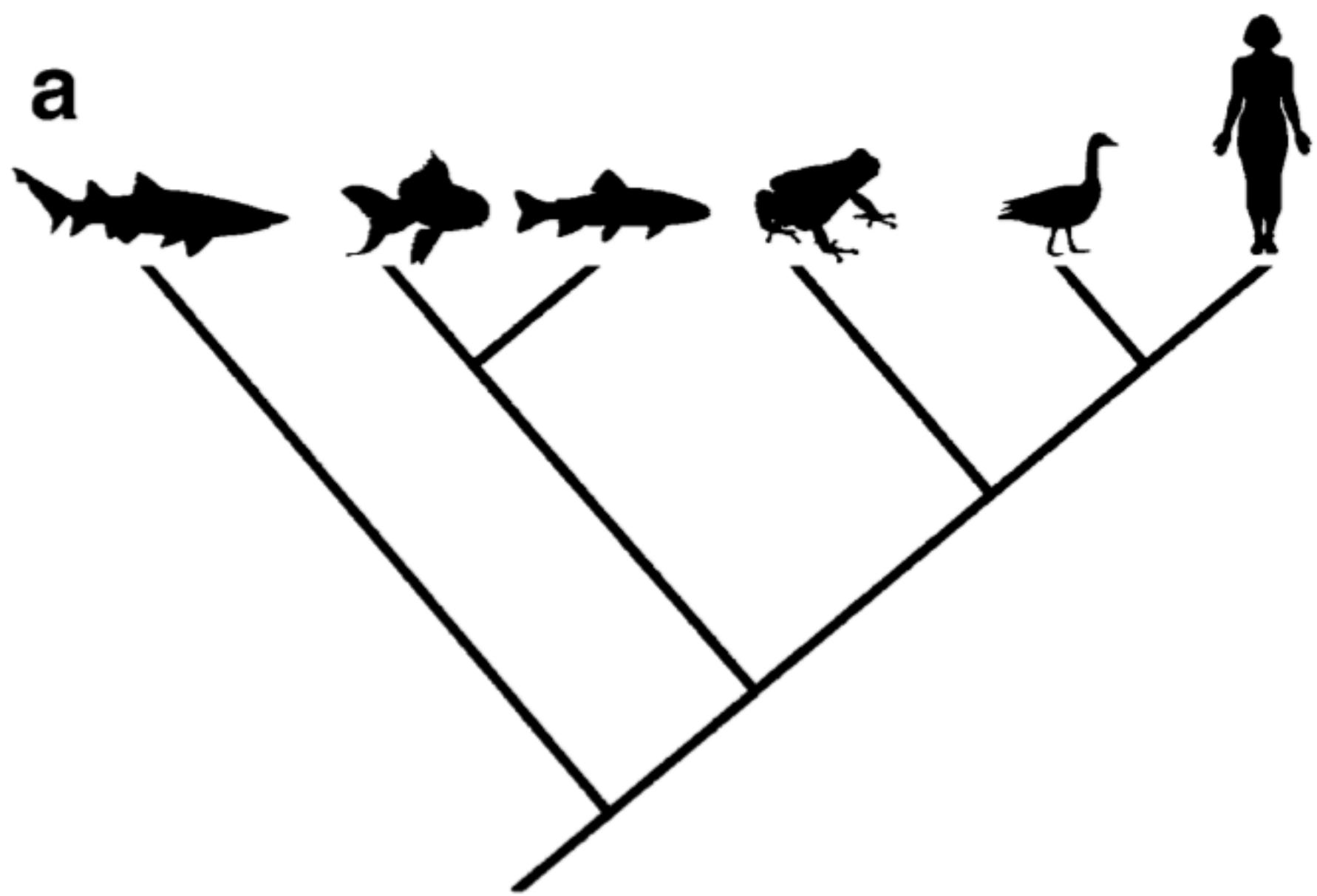


In this (valid) tree it looks like the main line of evolution leads to humans and the rest of the species are offshoots



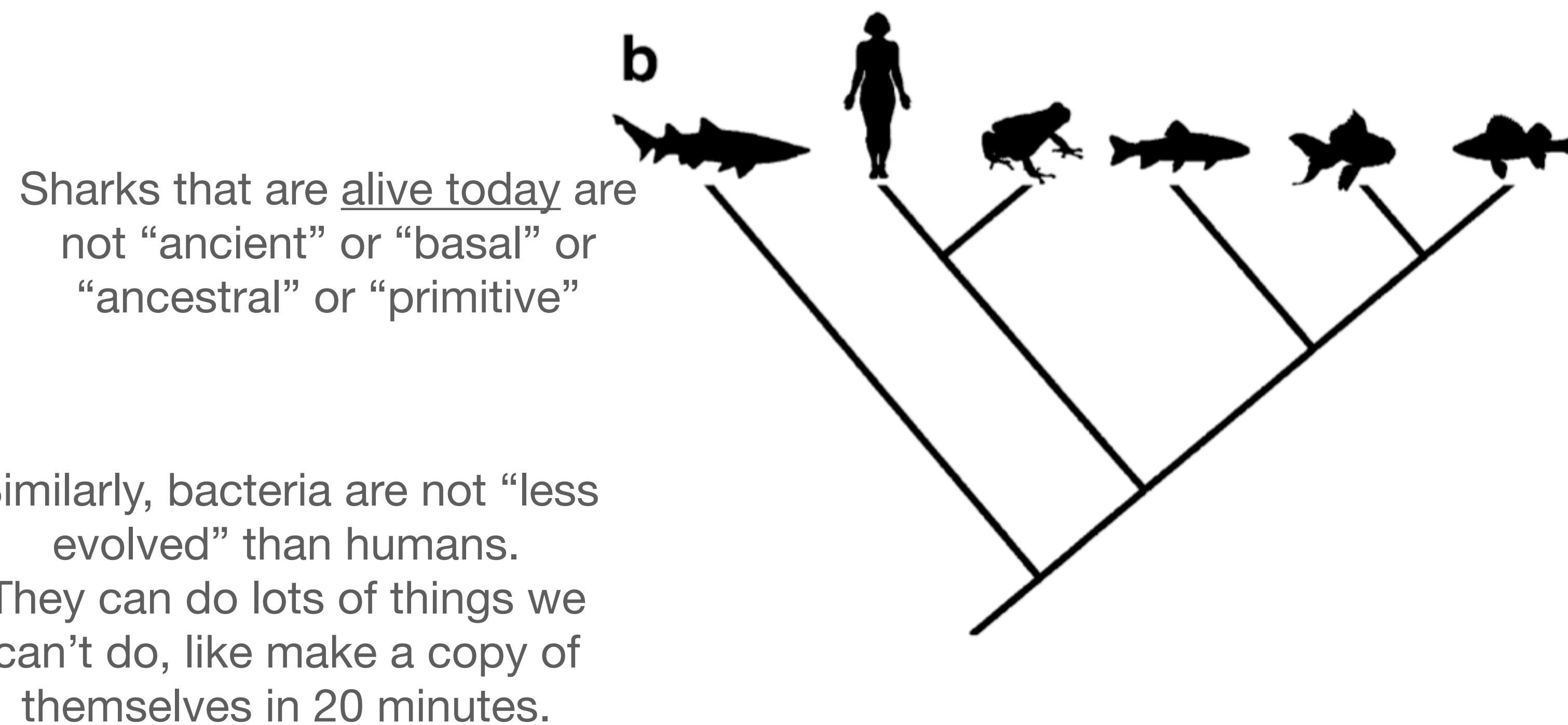
There is no “main line” of evolution leading to human or any other species

Note that humans are more closely related to bony fishes than either is to sharks

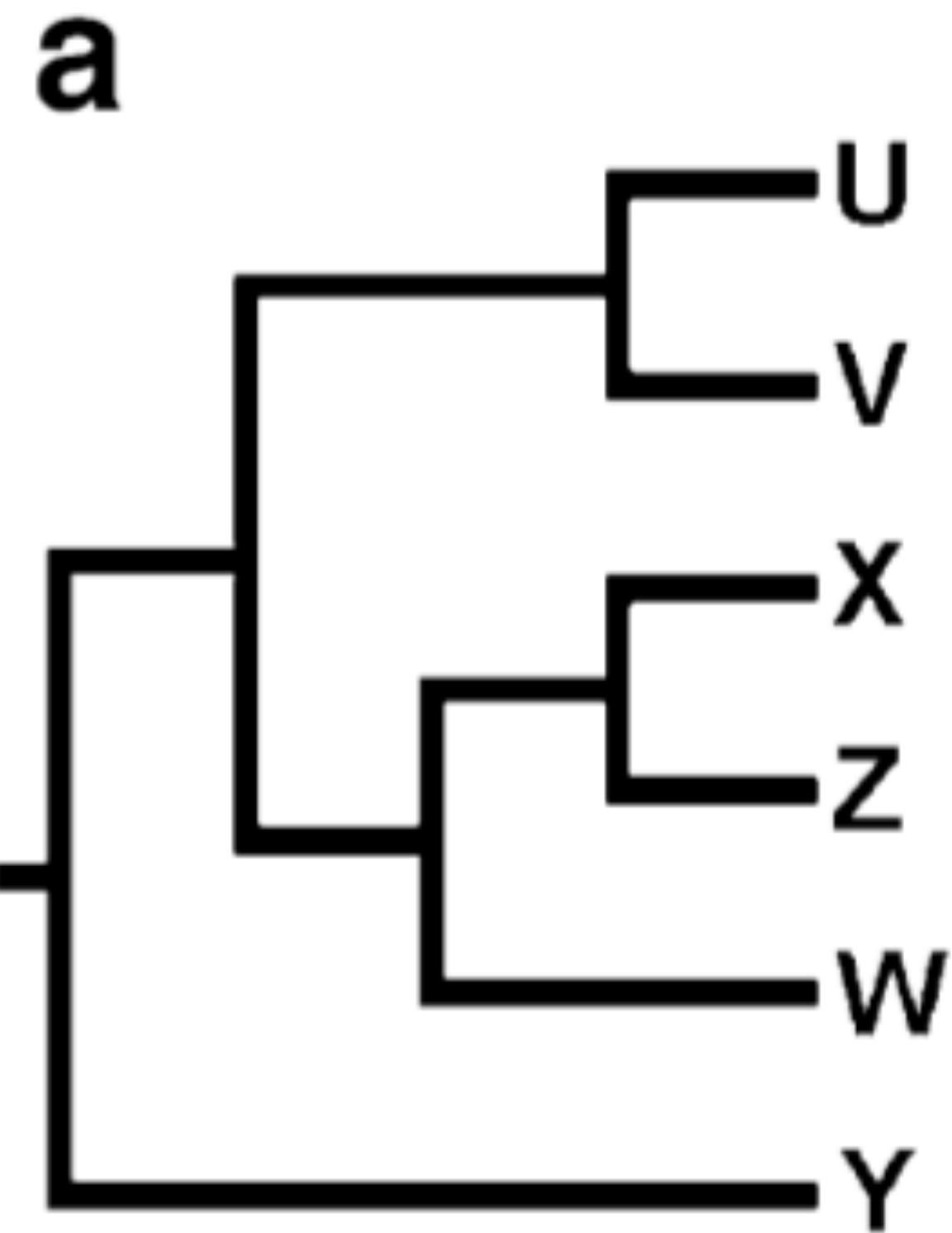


# Long branches don't mean that change hasn't happened

All of these existing species have been evolving for exactly the same amount of time since they diverged from their common ancestor



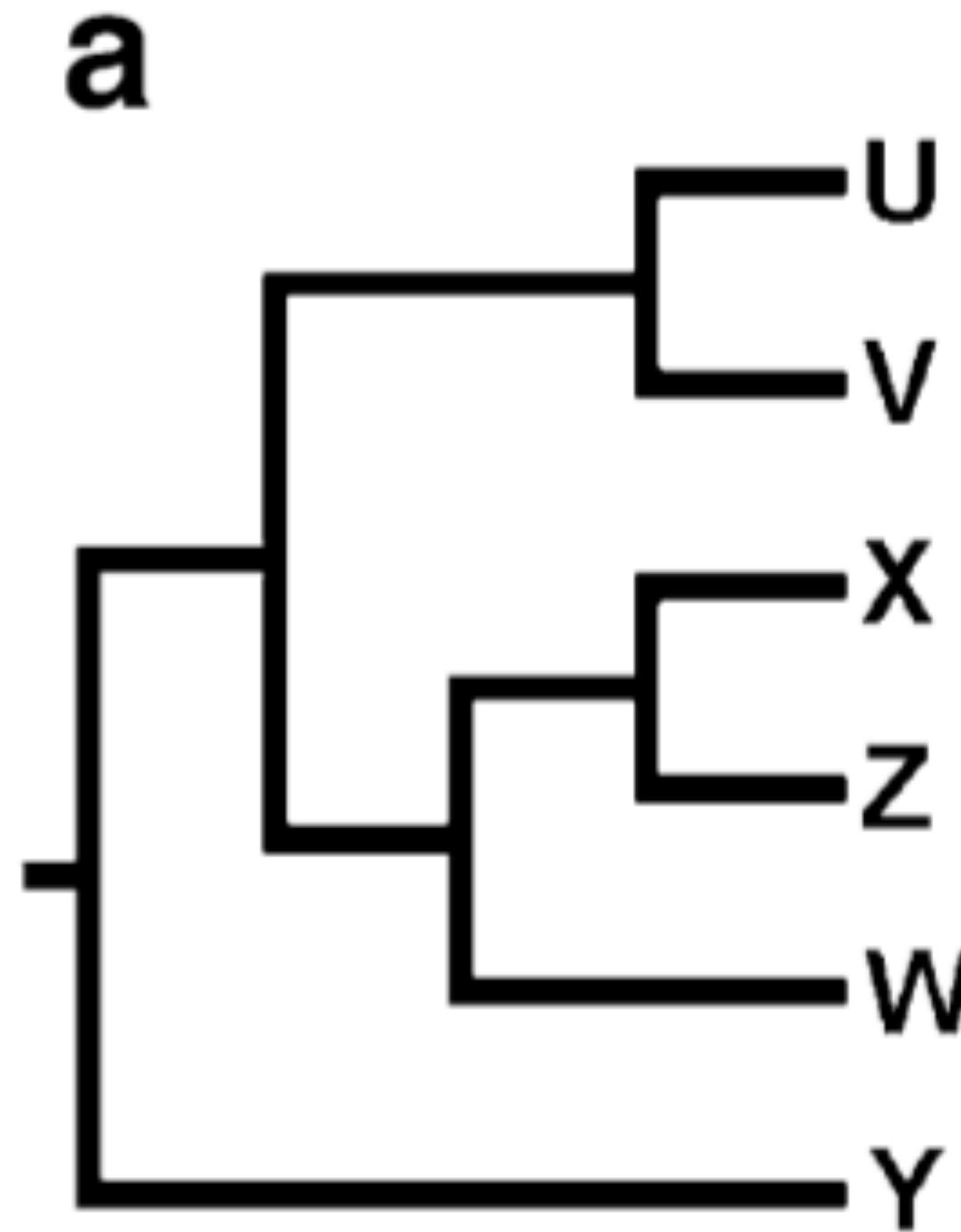
# Cladograms just show branching patterns



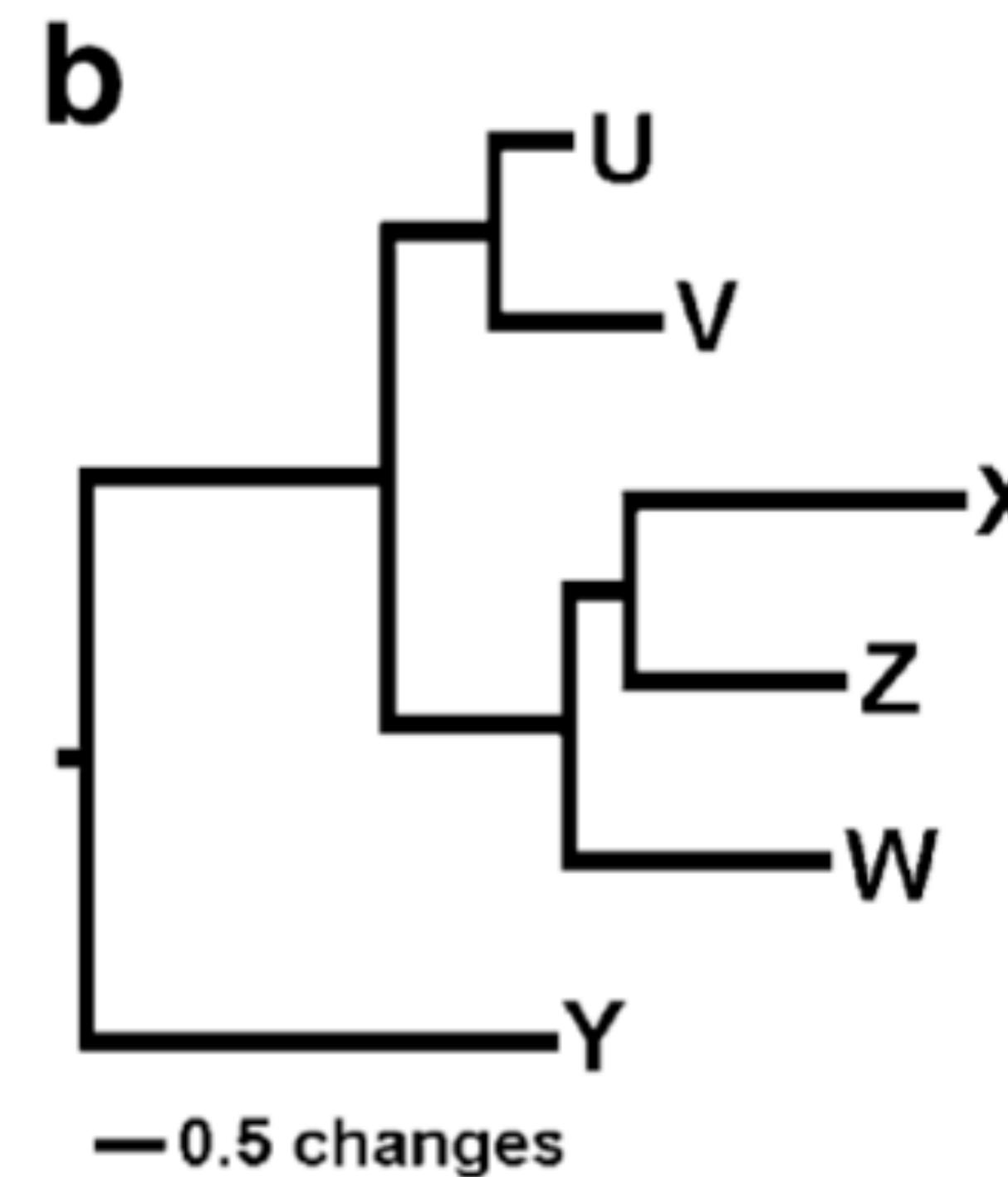
In this cladogram, branch lengths don't have any particular meaning

In phylogenograms branch lengths are proportional to divergence

Cladogram

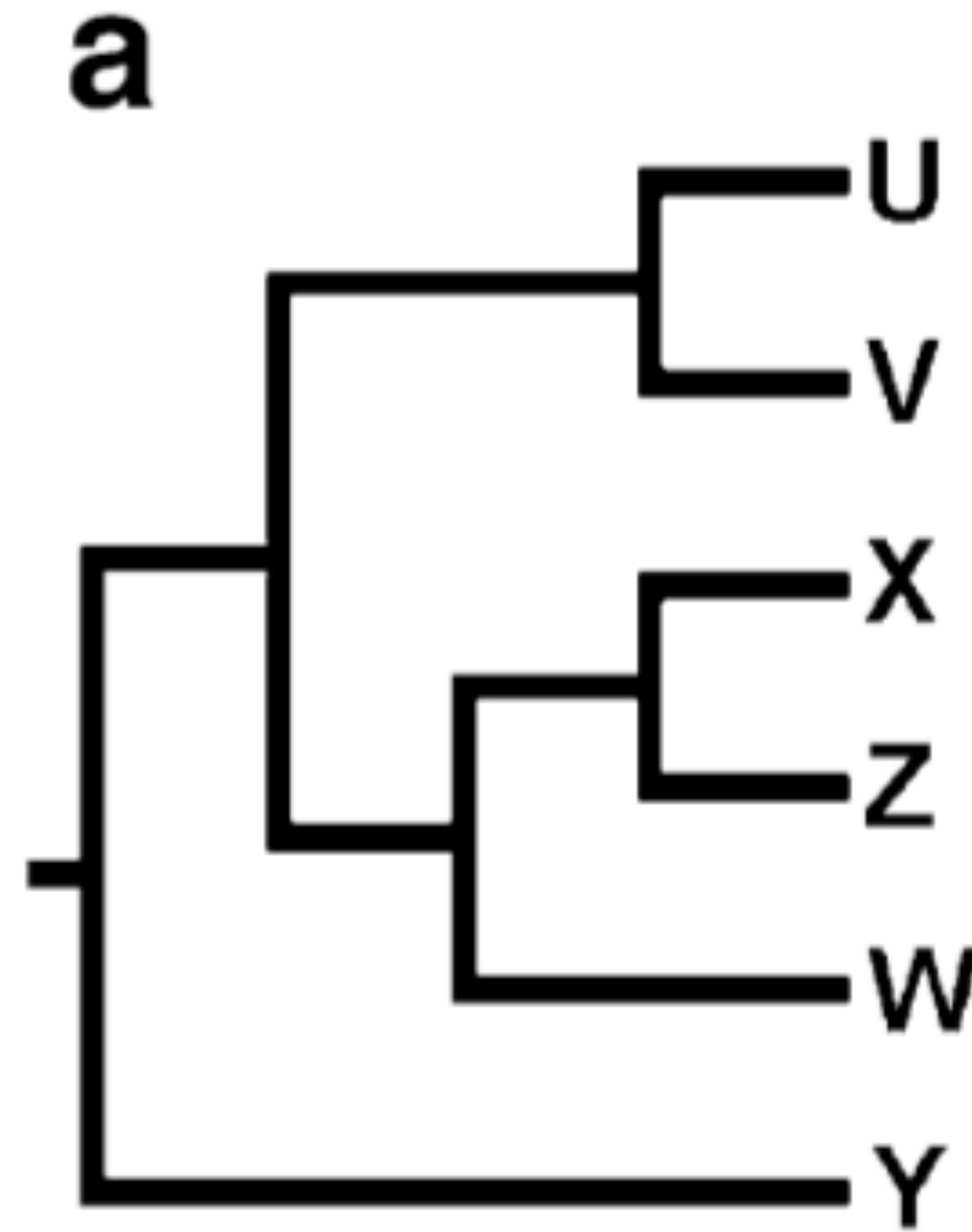


Phylogram

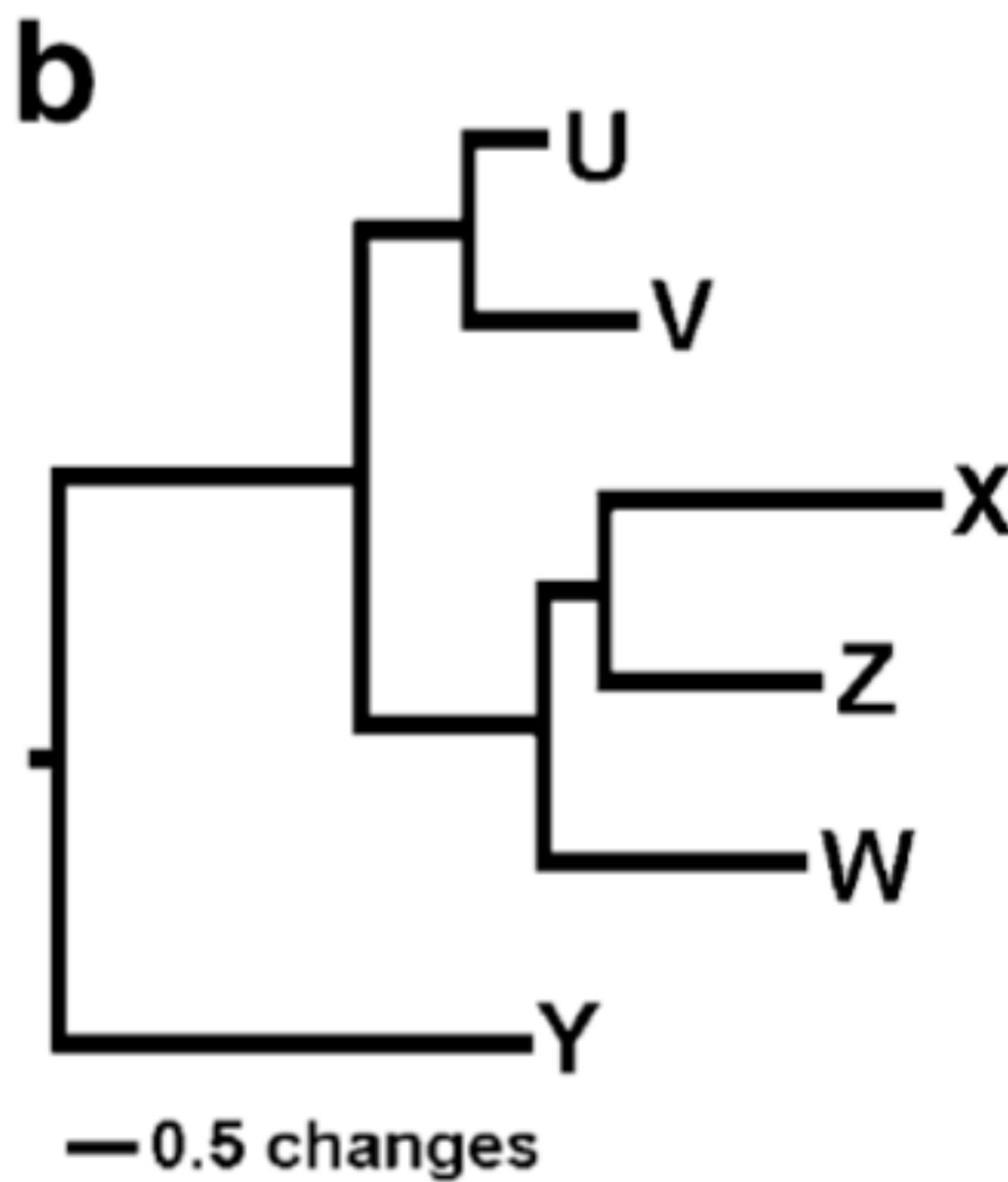


# Some phylogenograms are time scaled

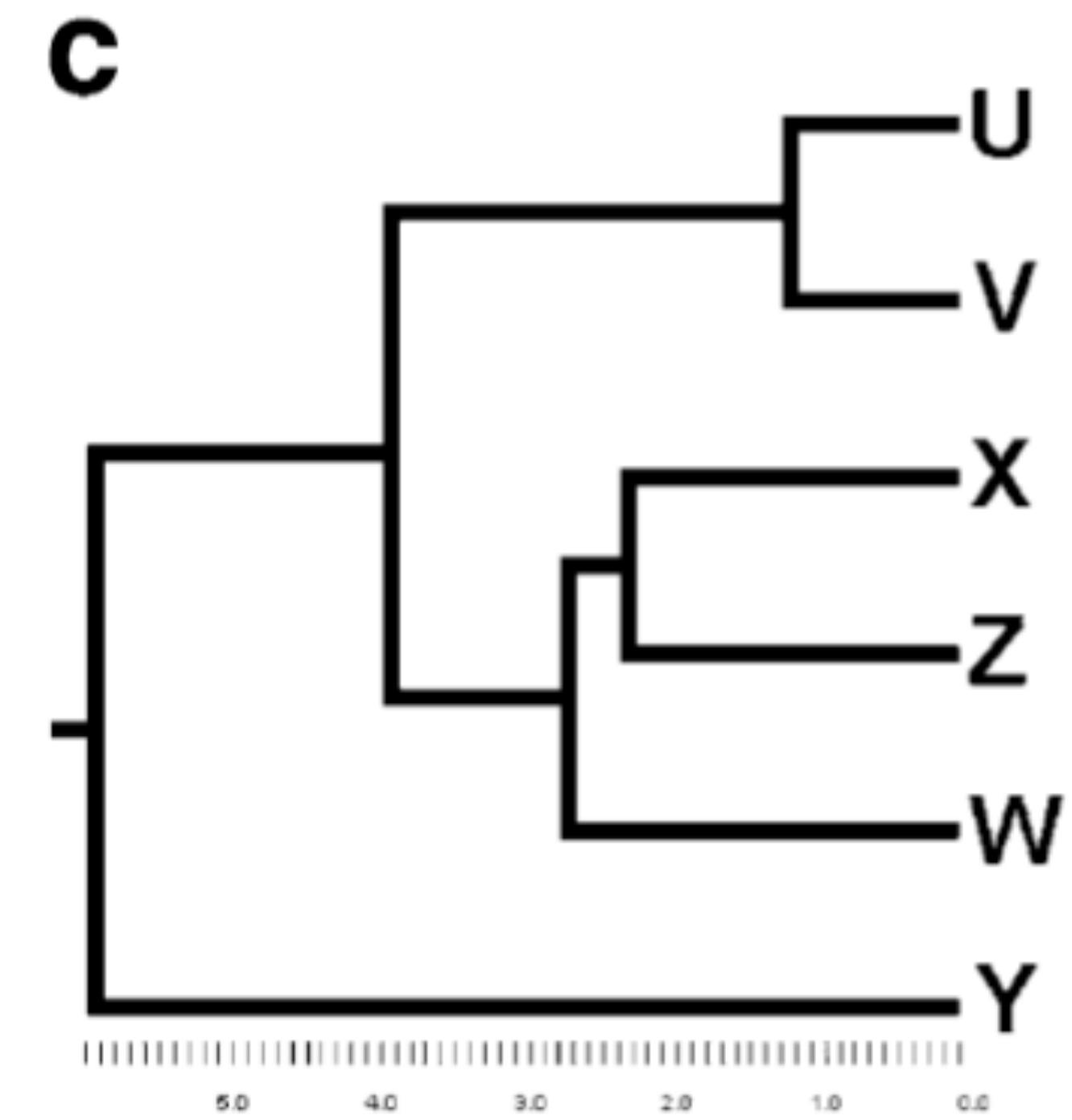
Cladogram



Phylogram



Time-scaled phylogram  
(sometimes called chronogram)



You need some additional information (fossil record, rate of evolution) to make a tree like this

The carnivore phylogeny we were looking at before is a time scaled phylogram

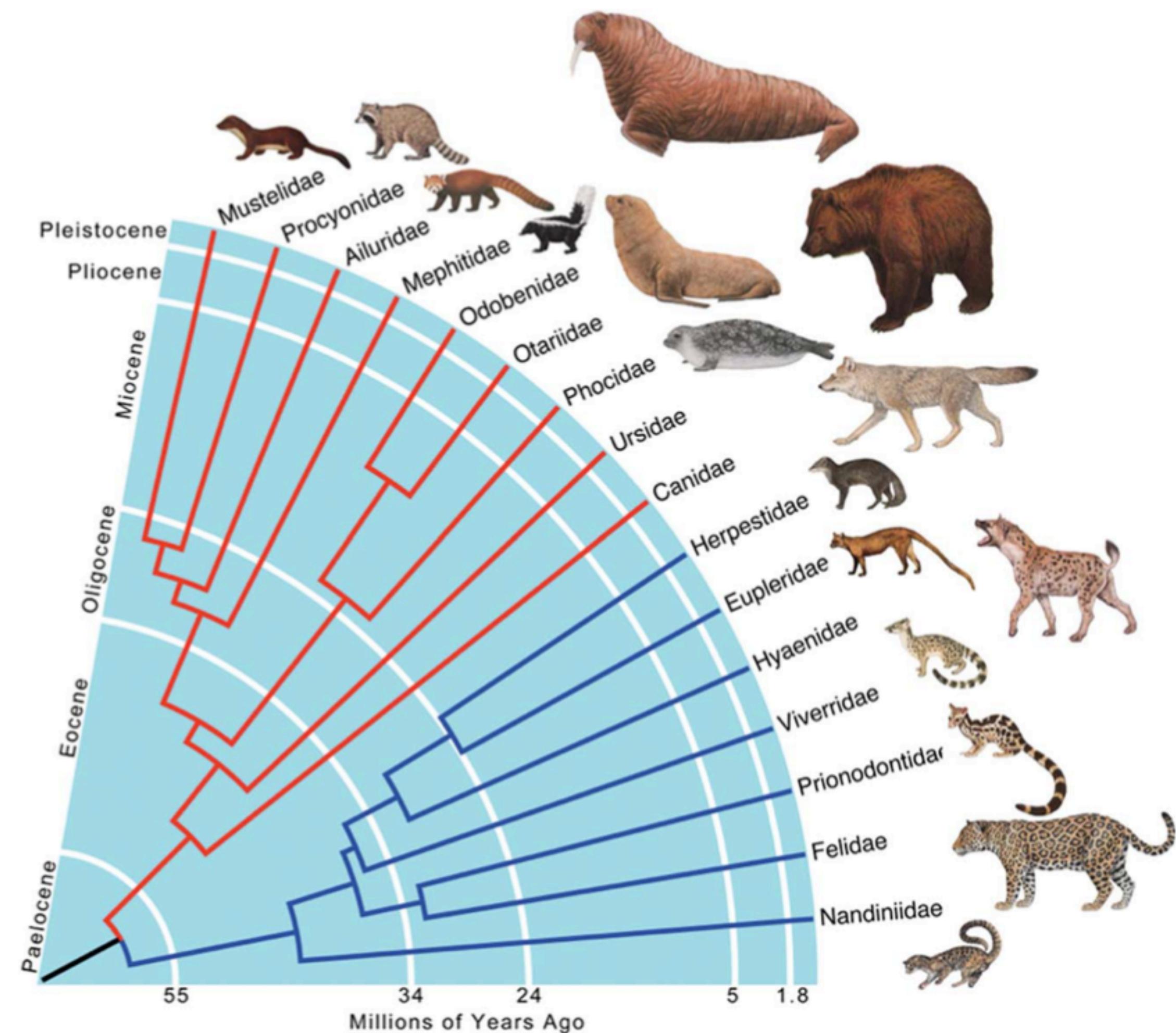
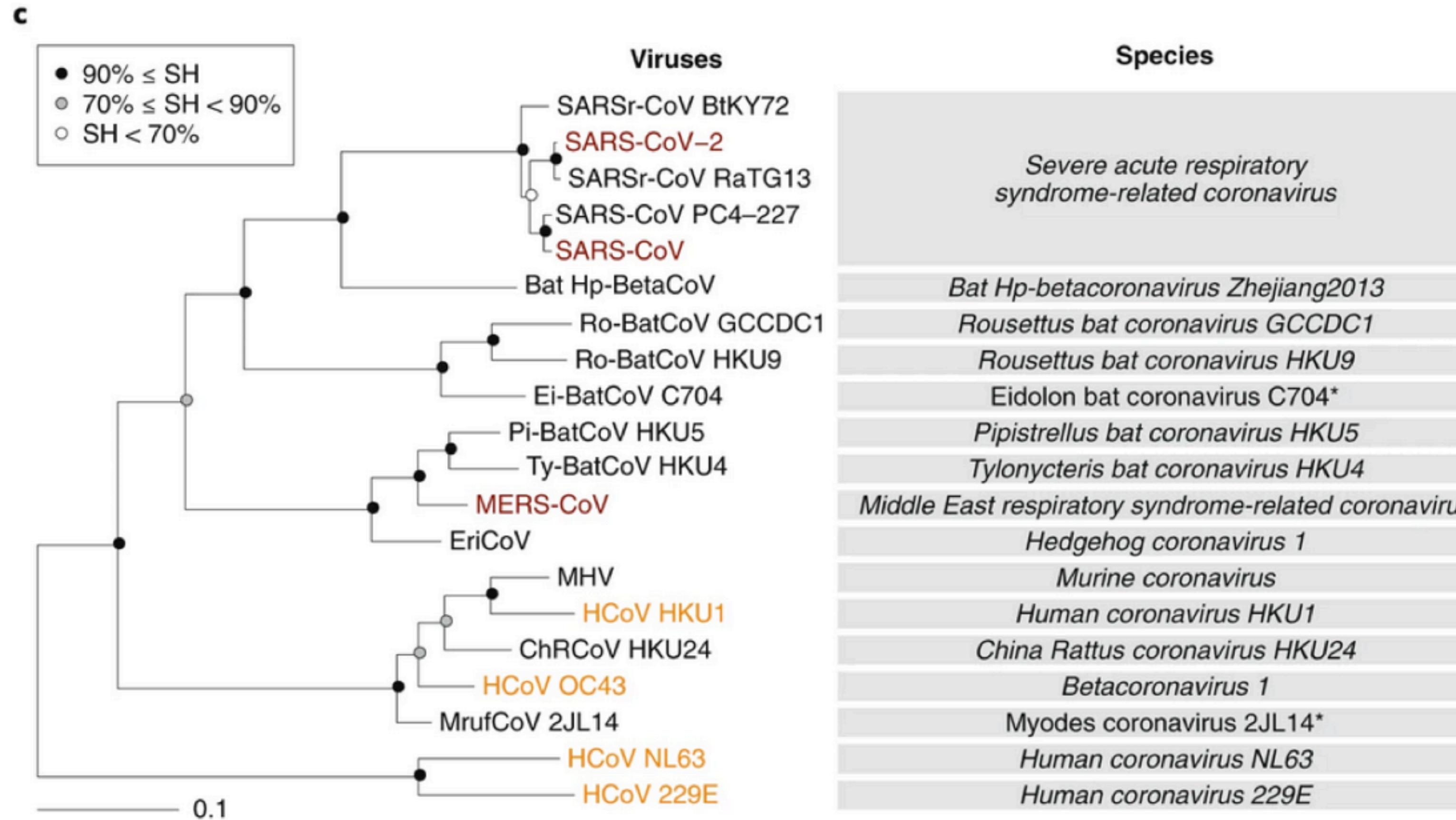


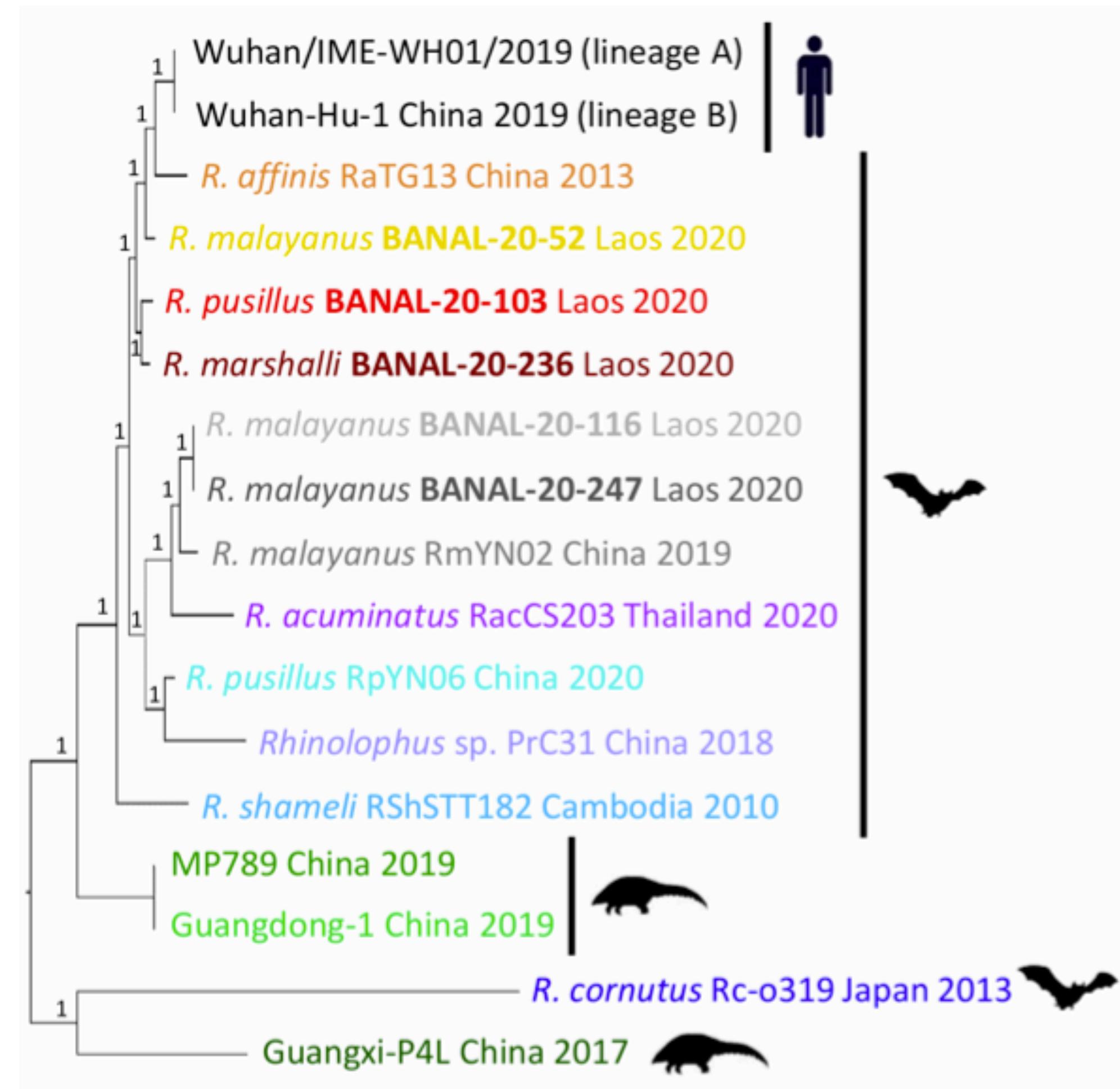
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# Answer three questions about the coronavirus tree below

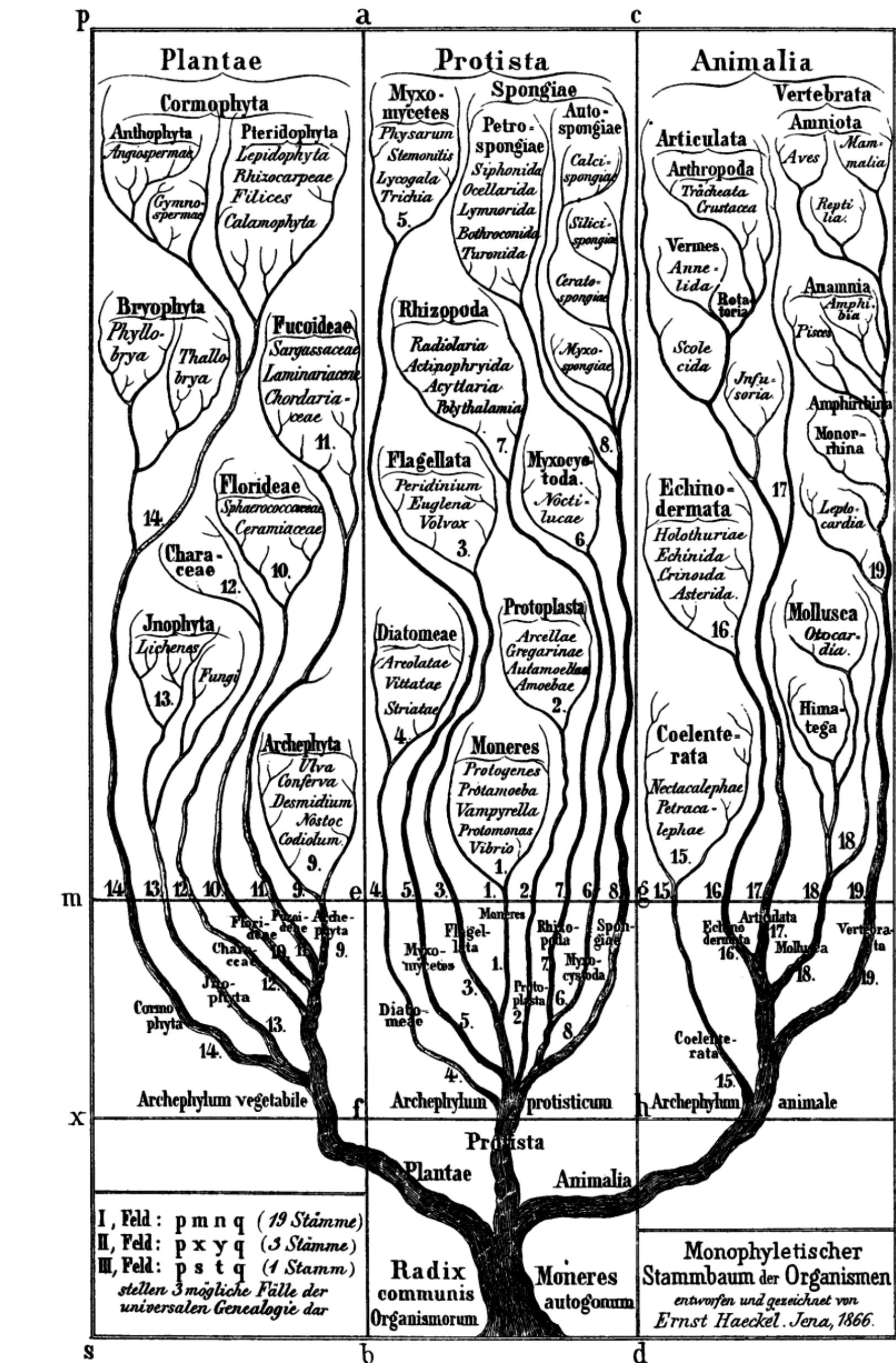
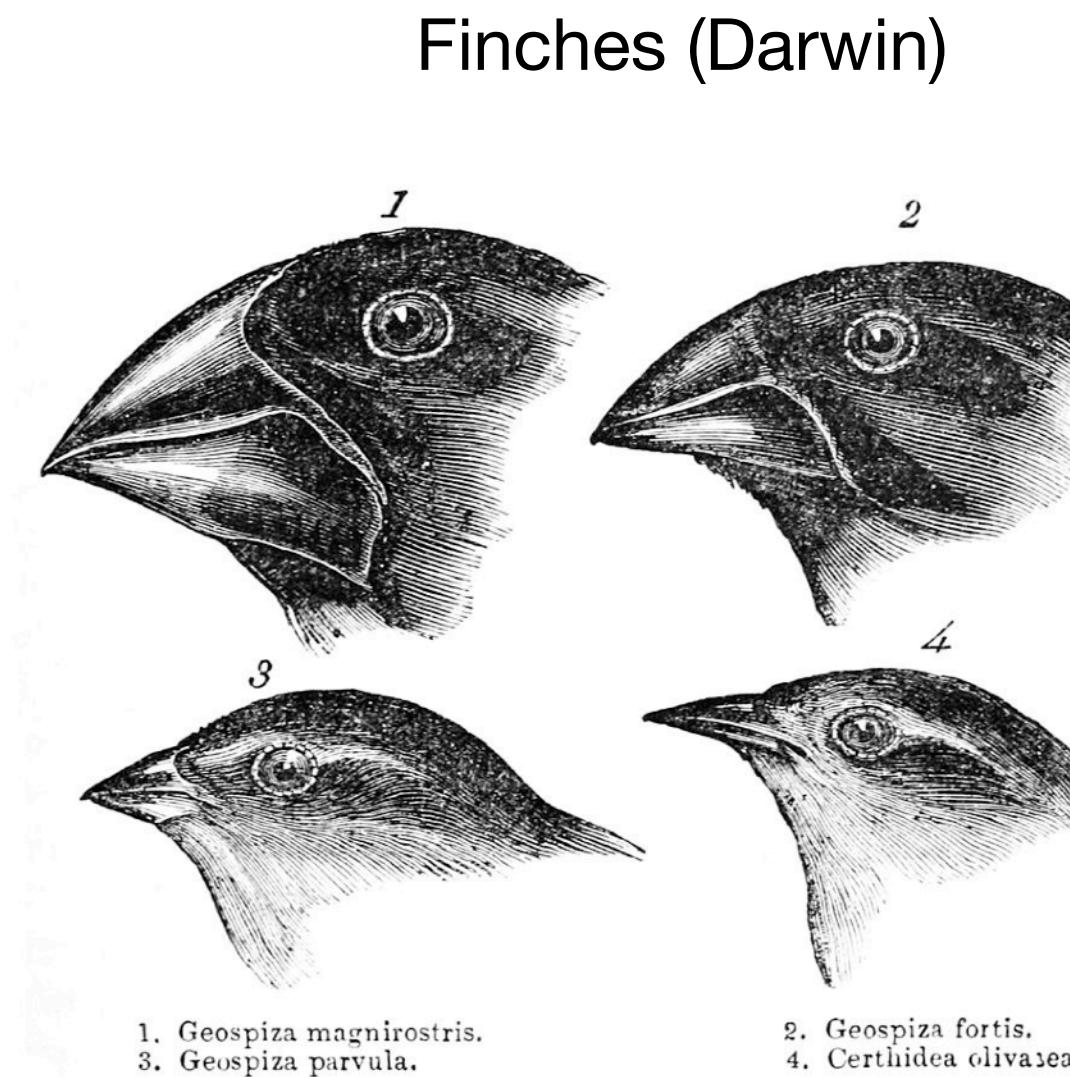


- Which of the four “common cold” CoVs (golden labels) are most closely related to SARS-CoV and SARS-CoV-2?
- What virus is most closely related to the original SARS-CoV (labeled SARS-CoV)?
- Is it possible that there are other viruses more closely related to SARS-CoV-2 than the bat-derived RaTG13 shown here?

# People are hunting for closer ancestors of SARS-CoV-2



# People used to make phylogenies using morphology and other traits

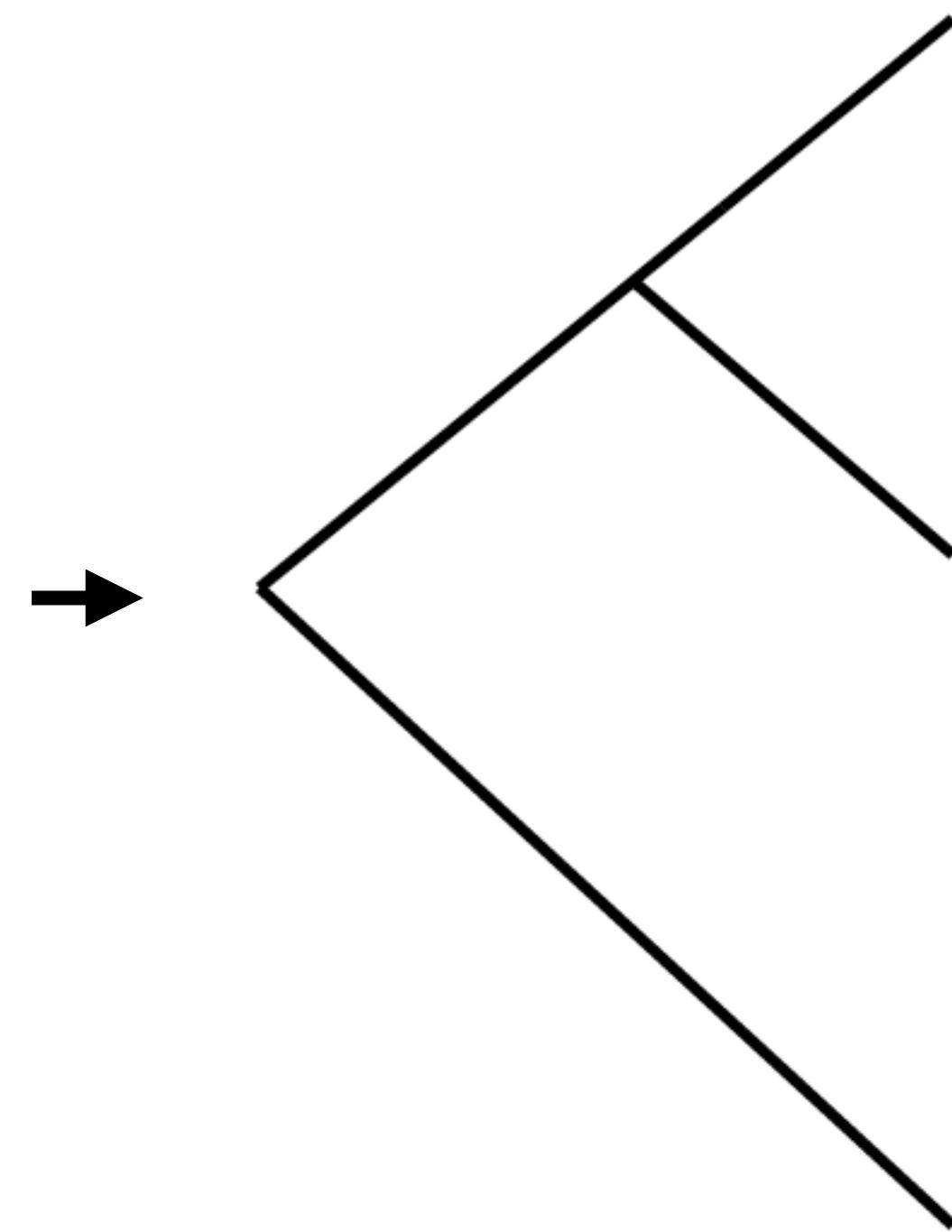


# Now phylogenies are almost completely based on nucleic acid or protein sequences

**Next time:**

How do you use MSAs to create trees?

How do you know if your tree is any good?



GAGGTACACACGCATGGTCATCATCATCATGGTCATTGCATTCTGATCTGCTGGGTGCCCT  
GAGGTACACGCGCATGGTCATCATCATCATGGTCATTGCATTCTGATCTGCTGGGTGCCCT  
GAGGTACACACGCATGGTCGTCATCATCATGGTCATCGCATTCTGATTTGCTGGTTGCCCT



ring-tailed cat



raccoon



kinkajou