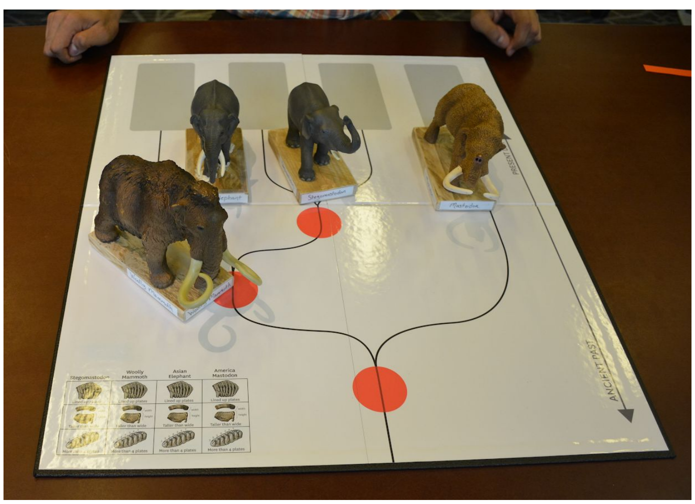
Elephant Evolution
Activity Facilitation Guide
Cart or Table Activity

Materials and Set-Up

MATERIALS:
Elephant Tree Game Board
Elephant Tree Diversity Board
Elephant Toys on their stands (4) - Asian elephant, American mastodon, Woolly mammoth, and Stegomastodon
Elephant Teeth in their boxes (4) - Asian elephant, American mastodon, Woolly mammoth, and Stegomastodon
Trait tokens - (3) - lined up plates, more than 4 plates, taller than wide
Tooth Diagram
Dry erase marker
Eraser
Calipers

SET-UP:

Start with the Elephant Tree Game Board open and the four toys randomly placed on it. Have tokens, diagram, and the teeth close-by for easy access, with Asian elephant tooth closest.



American mastodon

Stegomastodon

Woolly mammoth

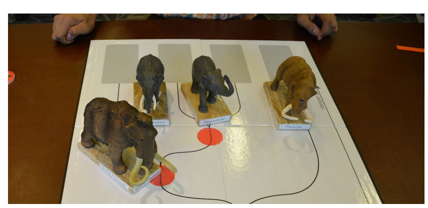
Asian elephant

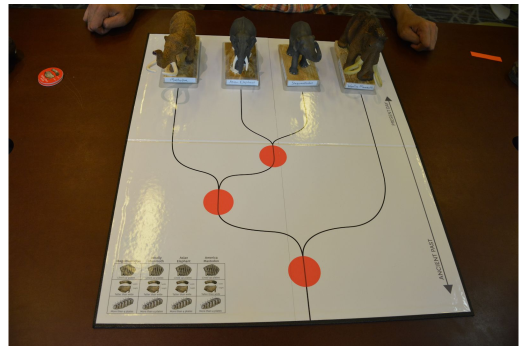
Elephant Evolution Activity Facilitation Guide

Activity Goal	Visitors create an elephant evolutionary tree using teeth from 4 elephant relatives.
Activity Summary	Visitors are presented with 4 elephant relatives--an Asian elephant, a woolly mammoth, a *Stegomastodon*, and an American mastodon. They are asked to hypothesize which are most closely related. Roles are then assigned--field researchers, who report on evidence they "find in the field" (3 fossil teeth and a modern Asian elephant tooth), and a lead researcher, who is responsible for organizing data on the evolutionary tree. The team works together comparing key features and working out the evolutionary relationships. Then they revisit their hypothesis, see how their thinking has changed, and they are given a question--when on the tree did adaptations to eating grass arise?--that they use their tree to answer. A fuller elephant tree is then revealed, allowing visitors to explore the great diversity of the elephant lineage in more detail; with their new tree training, they are able to ask more questions and make new discoveries together.
Learning Objectives (what visitors think, feel and do during the activity)	In the course of doing this activity, visitors will: -Make observations of, describe and compare the teeth of extinct and extant elephant relatives. -Use an evolutionary tree to show hypotheses about evolutionary relationships -Use specific characteristics of the teeth to work out how closely the animals are related -Use the tree to answer questions about when different traits were acquired along the elephant lineage -Discuss, explain, and debate with family members to make hypotheses, and make decisions while building the tree -Feel like they are doing science
Learning Outcomes (new understandings or changes in perspective that result from activity)	We anticipate that visitors who participate in the activity are more likely to: -Begin to understand more about how scientists use shared derived characters to work out relatedness. -Better understand how to make and read evolutionary trees and why and how scientists use them to represent hypotheses about relatedness, to explore and generate questions about evolution of traits, and to represent shared features among living things. -Understand that certain skeletal features are more useful than external features for investigating relatedness between living things.

	-Think more critically about what the distant past was like. For example, if elephants were so much more diverse in the past, what else was different? And what can we expect for the future? -Feel more comfortable and confident engaging with science, independently and as a group or family.
Target Audience	Families with children 8-12, but adaptable for all.

Activity Flow

What to say	What to do
HOOK [INSERT YOUR OWN HERE]	Differentiate according to audience
INTRODUCTION Every living thing, every species on earth is related. And one thing that biologists and paleonotologists want to understand is how different species evolved over time, to make the huge biodiversity that we see today, and how different species evolved or branched off from one another, from early common ancestors. One group of branches that can be really interesting to look at is the one for elephants and their ancient extinct relatives. Will you help me investigate the relationships of these?	[Point to the toys]
GUIDED PARTICIPATION **Toys - orientation to tree, make a hypothesis** Let's take a look at these toys--do you recognize any of them? Right, we have an Asian elephant,	

which is still alive, and three extinct elephant relatives - a mastodon, woolly mammoth, and stegomastodon. Have you seen an evolutionary tree before? We put the species at the tips of the branches. Ancient past is at the bottom. Going forward this way is evolution happening, split, split again. It’s like a family tree, but we’re talking about species. We’ll put the toys at the end of each branch. So this is like a lineage. There is an ancient ancestor and over time that branch splits, and later that branch splits again.	
So if you look at these toys, do you have ideas about which two are most closely related, so which two are most similar?	Point to the lines and follow them as you talk this through.
[VISITOR ACTION]	
Ok great, so to represent your hypothesis we will put those two here, where the split point is very recent, not that long ago, the closer the split points are, the more closely related they are. If the split is close to the top it means they are more closely related. If the split is down here, a long time in the past, it is a more distant relative.	Place the pair at the top two spaces If they are hesitant, remind them that this is just their starting hypothesis and they can update it as they get more evidence.
Then this split would lead to the next closely related. Then which comes next?	Place others.
[VISITOR ACTION]	
So you put the [xxx] as the most distant relative, right?	Place the next toy.
Why did you sort them this way?	
[VISITOR RESPONSE]	
Those are great observations. So this is your first	

hypothesis. But you could probably use more evidence than what you get with toys, right? Scientists have to look at the evidence to see if their hypotheses are supported.

One thing paleontologists know is outside appearances can be deceiving and it's helpful to look at the skeleton to understand similarities and differences that are more than skin deep. In this case--and often with mammals--the teeth give us a good clue.

Asian elephant tooth - orientation just to the tooth

We are going to be looking at single teeth from each of these elephant relatives.
Elephant teeth are kind of amazing.
Here is a tooth from this one, the Asian elephant. What do you notice about it?

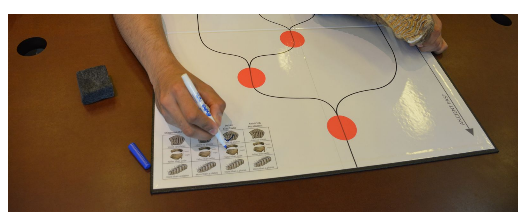
Bring out the elephant tooth and **put it in someone's hand**

That is one molar. Do you know where your molars are? So that's just one. Here is the chewing surface. This is the crown, this is the root. The gums go over like this. And these are called plates.

As they hold it you can point to the diagram or to the tooth they are holding to point out key features.

If we were to mark certain traits for this tooth on your chart here, would we say that it has lined up plates? What about more than 4 plates? And is its crown taller than it is wide?

Mark these traits on the board as they give you the answers



Great! Now, as a group, you are going to use teeth from the extinct elephant relatives to work out how they are related. You will be putting together a tree and may need to adjust your hypothesis here.

Assign roles

To get started, I need a volunteer to be Lead Researcher. Great! Everyone else will be Field Paleontologists. Lead Researchers, you are in charge of gathering evidence from your colleagues here and using that evidence to make the tree. You can use the chart that we started here to start to collect the evidence. Then you can use the markers to show where you think the traits evolved and what that means for how the elephants are related. Use these to check your hypothesis and create a tree.

Field paleontologists, here are your boxes of evidence. Each of you is assigned one elephant relative that you are the expert for. The box has a single tooth from that relative. Listen to the lead researcher here and follow their instructions.

As a reminder, you'll be looking for these traits - lined up plates, more than 4 plates, and crowns that are taller than wide.

[Visitors work; facilitator steps back].

Great! You have collected all your data. Now you should be able to use that information to place the traits and check where the elephant relatives go.

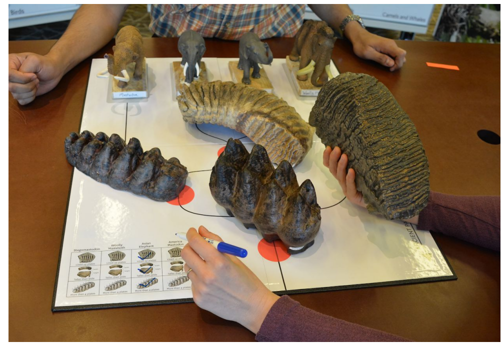
[Lead researcher places trait tokens and rearranges elephant toys]

Happy? Do your field assistants agree?

Excellent job. You looked at teeth and used traits to work out how the animals are related, which is exactly what paleontologists do to work it out, but with more traits. You've worked out the evolutionary relationships. Is there anything surprising to you about what you found out?

[VISITORS RESPOND]

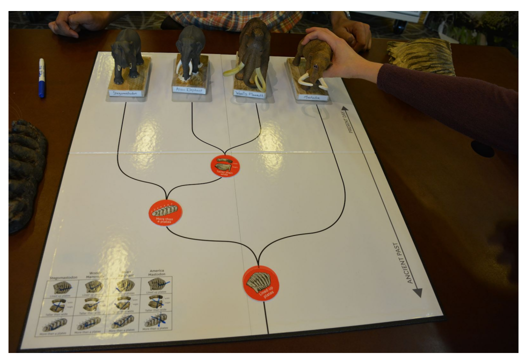
Talk about Diet



Distribute the other three boxes.

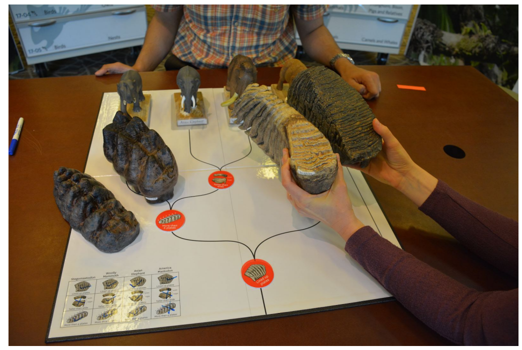
Remind them that they are looking at single teeth.

And let them work the rest out. Encourage them to work together.



If the Lead Researcher needs prompting, ask: Which trait would you like to start with?

If they get stuck on the order of the traits, remind them that trait at the bottom is the trait that the common

When we make these trees, we can use them to work out other things, to answer some big questions. Looking at this tooth (Asian elephant), what do you think elephants eat? Do you think the others were good at eating grass? What do you think these other two ate? So if these two are good at eating grass, can you point to the branch on the tree where eating grass may have evolved? Why would you say that? Now, had you seen these types of extinct elephants before? So I'd like to show you something maybe you haven't seen before. **Big tree** So we've been looking at just four species of elephant relative (point to those on the tree). Here we have a lot more, and this is only a section of those. What are some things you notice looking at this? Do you remember you showed me where the ability to eat grass evolved on your tree--can you do it with this tree? So, before about 8 million years ago, there weren't elephants that were well adapted to eating grass, but after there were a bunch. We can use the tree to work that out. Do you have any questions?	ancestor of all these animals had; so all these animals would share that trait. And so on. Respond based on what they point out.  Depending on how they answer, use this opportunity to summarize what the tree shows and reinforce how the teeth showed them something they couldn't tell from the outside. Bring out the big tree. Once they have plotted the evolution of grasslands, if they are very interested in the tree and you have the time, you can go into more about where all these elephants lived, how they got there, and what happened to them. From Advait: This species of mammoth went extinct only about 4,000 years ago, around the same time the Egyptians were building the pyramids. Between 50,000 and 4,000 years ago, we had 16 species of elephants and their relatives on every continent except Antarctica and Australia. There were up to 7 species in the United

	States alone! Today, three species remain: the African savannah elephant (*Loxodonta africana*), the African forest elephant (*Loxodonta cyclotis*), and the Asian elephant (*Elephas maximus*). Populations of all three species are declining, with Asian elephants at a much higher risk of extinction.
WRAP UP/RELEASE **[INSERT YOUR OWN HERE]**	Identify the science skills the visitor used in the activity. Direct them to other parts of the museum or elsewhere for related content.

Museum Connection

Advait Jukar, National Museum of Natural History Peter Buck Deep Time Postdoctoral Fellow

“Paleontology helps us understand what we’ve lost in the distant and recent past. I'm standing here with a specimen of wooly mammoth skin and hair from Siberia. This species of mammoth went extinct only about 4,000 years ago, around the same time the Egyptians were building the pyramids.

“Between 50,000 and 4,000 years ago, we had 16 species of elephants and their relatives on every continent except Antarctica and Australia. There were up to 7 species in the United States alone!

“Today, three species remain: the African savannah elephant (Loxodonta africana), the African forest elephant (Loxodonta cyclotis), and the Asian elephant (Elephas maximus). Populations of all three species are declining, with Asian elephants at a much higher risk of extinction.

“I love elephants not only because they're charismatic and have an incredibly interesting evolutionary history, but also because in many ways, they're like us; they live in complex social groups and exhibit a range of emotions. If we let the remaining species go extinct, that entire branch of the mammal tree of life is gone forever. I hope that never happens."

Background Information

Basic proboscidean evolution: groups, timing, migration, diversity

Today's elephants are part of the order Proboscidea which consists of modern elephants and their extinct relatives such as mastodons, mammoths, and gomphotheres. While today there are only two surviving elephant **genera**, the African and the Asian elephant, their evolutionary history is much more diverse.

<u>First Proboscidean Radiation</u>

The first proboscideans evolved in Africa in the Paleocene epoch. One of the earliest recognized proboscideans, *Phosphatherium escuilliei*, lived 58 million years ago (mya) in what is now Morocco. Proboscideans are most well known for their tusks, trunks, and immense size, but early members of Proboscidea reveal that these features weren't always present in this group. *Phosphatherium*, for example, only reached a shoulder height of about one meter and entirely lacked a trunk. *Moeritherium* and *Numidotherium* are other early proboscideans from Africa that appeared during the Eocene. *Moeritherium* also lacked a proper trunk, though it is thought that they may have had a mobile upper lip, while *Numidotherium* had a small trunk similar to that of a modern tapir. These and other early proboscidean taxa that spread throughout Africa from the Paleocene through the Oligocene (58-24 mya) are considered a part of the first of three major proboscidean radiations. Proboscideans that emerged in the Miocene are considered to belong to the second proboscidean radiation, while the third radiation consists of proboscidean taxa that appeared between the end of the Miocene (~7 mya) through today.

<u>Second and Third Proboscidean Radiations</u>

Proboscideans may have first evolved in Africa, but both the fossil record and modern elephant distributions show us that they didn't remain confined to Africa forever. Upon the closing of the Tethys Sea, the landmasses of Africa and Eurasia became reconnected. This allowed members of the order to disperse from Africa into Asia, Europe, and eventually North America and South America as well. The migration of proboscideans from Africa into Eurasia first began in the early Miocene about 22 million years ago and is thought of as part of the second radiation of Proboscidea. The family Deinotheriidae, for example, first appeared in Africa in the late Oligocene (~28 mya), but by the early Miocene (~21 mya) they had spread across Eurasia as well.

Mammutidae:

Mammutidae (mastodons) originated in Africa in the early Miocene (~22 mya), but by the late early Miocene (17-19 mya) they had spread into Europe. In the middle Miocene (11-16 mya) they had migrated across Asia, and eventually entered into North America by crossing the Bering Land Bridge. Mastodons are found in the fossil record of North America as recent as only 12,000 years ago.

Gomphotheriidae:
The gomphotheres were a group of proboscideans that often featured two upper tusks and two spatulate lower tusks. By the early Miocene the gomphotheres had already spread through much of Africa, Europe, and Asia, soon followed by migrations into North America via the Bering land bridge in the middle Miocene. In the Pleistocene, the gomphotheres even reached South America.

Stegodontidae:
The stegodontids are a family of proboscideans that are thought to have evolved from gomphotheres somewhere in Asia. They looked a lot like modern elephants on the outside, but had very different teeth. The stegodontids lived from the early to middle Miocene into the late Pleistocene and were spread across Asia and Africa.

Elephantidae:
Elephantidae consists of elephants (including those still alive today),mammoths, and other extinct relatives. They originated in Africa about 6-8 million years ago during the Miocene and members of the family dispersed into Asia and Europe multiple times through the mid and late Pliocene. When mammoths went extinct ~4,000 years ago, that left the modern Asian and African elephants (*Elephas maximus*, *Loxodonta cyclotis*, and *Loxodonta africana*, respectively) as the last surviving members of not only Elephantidae, but Proboscidea as a whole.

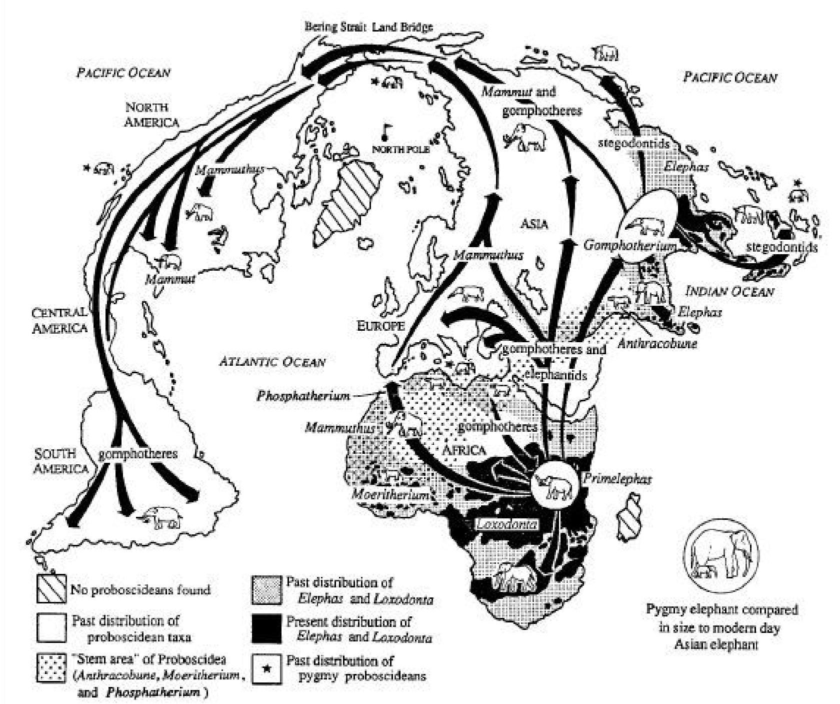


Fig. 3. A reconstruction of proboscidean world distribution pattern. Stippled and darkened areas in Africa and Asia show past distribution of Recent (Holocene) taxa, *Loxodonta* and *Elephas*, respectively. *Modified, with permission, from Ref. 6.*

Source: Shoshani 1998

See the Berkeley Proboscidea page:
https://ucmp.berkeley.edu/mammal/mesaxonia/proboscidea.php
See Shoshani 1998

Intro to Elephant Teeth: How they grow and are replaced

See Sanders 2017 Intro and General Discussion

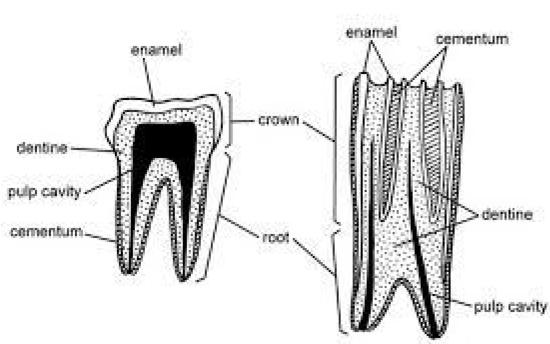
Unlike many mammals that have one set of baby (deciduous) teeth that are lost and replaced by a new set of permanent adult teeth, modern elephants have a distinctly unique form of tooth replacement. While human adult teeth lie in wait beneath our deciduous teeth and gradually shift vertically to take their place, elephants' teeth instead get replaced horizontally like a sort of dental conveyor belt. Elephants have teeth that are replaced by new teeth moving forward and pushing out the old ones as they get worn down. Elephants actually have six sets of teeth in their lifetime. They need all these extra sets as their diet consists of tough vegetation such as grasses and bark that require extensive grinding to break down. As a result, their teeth get worn down over time and need to be replaced. Most of the early proboscideans that evolved in Africa actually had vertical tooth replacement, similar to ours and most other mammals, but by the time mastodons and gomphotheres appeared, , proboscidean taxa had evolved this unique horizontal system of tooth replacement.

Video on elephant tooth development: https://www.youtube.com/watch?v=7vwaObde3Nk

Hypsodont teeth and the Environment

See Damuth and Janis 2011

Hypsodont is a term that is used to describe teeth that have a high crown. In contrast, brachydonty refers to a low-crowned tooth. The crown height of the teeth of an animal can tell us a lot about the animal's diet and feeding behavior. This is because animals that consume tougher, more abrasive foods are more likely to wear down their teeth over time and thus such animals tend to have evolved higher crowned teeth to accommodate this wear. Animals that consume softer foods experience less wear on their teeth, and therefore tend to be more brachydont. Early proboscideans are known for usually having more brachydont dentition, indicating that they were browsers that primarily consumed soft leaves. Later proboscideans, however, are more hypsodont and have more complex tooth surface patterns for grazing on more fibrous, abrasive grasses that require more extensive grinding to break down. It is also thought that soil ingested inadvertently while consuming foods close to the ground, such as grasses, may be largely contributing to the dental wear that is seen in grazers.



Source: http://www.life.illinois.edu/ib/462/Lab%203%20-%20Teeth.pdf

Background/life histories for 4 species in the activity

Elephas maximus: See Shoshani and Eisenberg 1982

The Asian elephant, *Elephas maximus*, was once distributed across a large portion of Asia, but today their range is largely limited to grasslands and forests across scattered portions of India and southeast Asia. These massive animals have thick, wrinkled skin that is covered in hair, though this hair thins as the elephants reach adulthood. The males can reach up to about 3.2 meters (10.5 feet) at the shoulder and they have pronounced tusks that are used for a variety of purposes such as clearing away trees, display, and as weapons. The females, however, only reach heights of about 2.5 meters (about 8 feet) and they usually lack tusks. Their diet consists of a wide range of plant material such as grasses and tree bark and their teeth are hypsodont with looped ridges of enamel to grind down this plant matter.

Mammuthus primigenius: See Adrian Lister's book on mammoths (Gale has a copy) Mammoths: Giants of the ice age

Mammuthus primigenius, also known as the woolly mammoth, lived in Europe, Asia, and North America largely during the Pleistocene epoch and went extinct in the Holocene about 4,000 years ago. They were covered in coarse fur and had a thick layer of fat that would have helped keep them warm in the frigid temperatures of the ice age. These mammoths also had large, curved tusks for removing bark from trees, digging up roots, and for combat. Both males and females had tusks, though female tusks were considerably smaller. Woolly mammoth teeth have a relatively flat ridge pattern similar to modern elephants that was used for grazing on grasses.

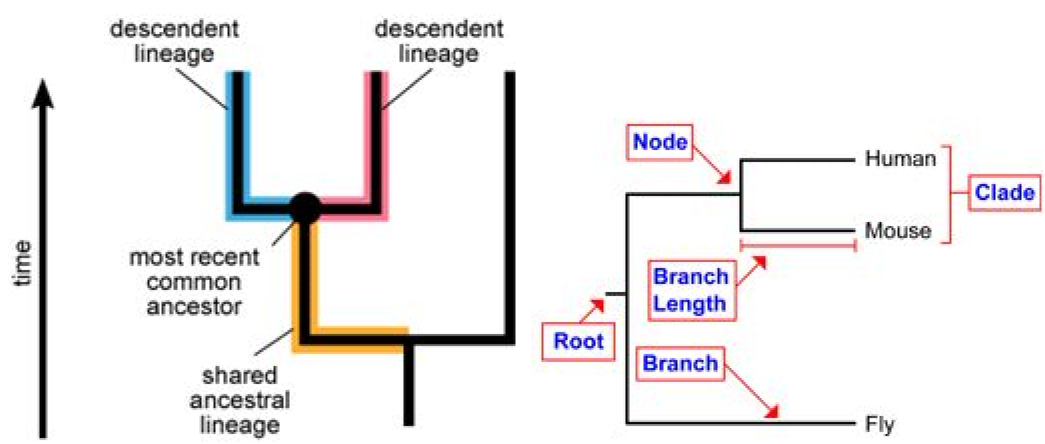
Stegomastodon

Stegomastodon is a genus of gomphothere from North America. *Stegomastodon* first appears in the fossil record in the Miocene, and persists into the early Pleistocene. At least three species are currently recognized as valid, *S. mirificus*, *S. primitivus*, and *S. aftoniae*. They weighed about as much as an average African elephant despite being shorter in stature. They were however more robustly built, with wider hips and thicker limbs. *Stegomastodon* had more advanced teeth for gomphotheres, with up to 7 ridges on their third molars, thus increasing the surface area for processing tough vegetation. They had slightly flat skulls, non-elongated mandibles, and only one pair of tusks in the upper jaw. Their teeth consisted of a series of blunt cone-like ridges with a groove going down the middle of the tooth, and weren't particularly high crowned. This suggests that they primarily ate leaves and twigs, but the greater number of ridges compared to other gomphotheres suggests that they could have eaten grass as well.

Mammut americanum: See Mammoths & Mastodons of the Ice Age by Adrian Lister
The American mastodon, *Mammut americanum*, lived in North and Central America from the Pliocene until their extinction ~12,000 years ago. Unlike mammoths and modern elephants, mastodons had bulbous, conical cusps on their teeth, indicating that they were browsers that used their teeth to crush wood material such as sticks and tree branches. Mastodons also had straighter tusks than mammoths that were likely used to break through branches as they moved through the forest. Around the time they went extinct, two species lived in North America, the American mastodon or *Mammut americanum*, and the Pacific mastodon, or *Mammut pacificus*.

Evolutionary Tree Primer

One of the biggest challenges that paleontologists face is trying to understand the complex relationships between all organisms, whether living or extinct. One way we try to accomplish this is by constructing **evolutionary (phylogenetic) trees** that act as visual representations of our hypotheses of these interconnected relationships. Each **branch** represents a particular lineage and each branching point of a tree (**node**) indicates the point where an ancestral lineage diverged into two distinct lineages. Therefore, each node represents the most recent common ancestor that is shared between all the groups following that node.



Source: https://www.ncbi.nlm.nih.gov/Class/NAWBIS/Modules/Phylogenetics/phylo7.html

To construct an evolutionary tree, we first need to determine the evolutionary relationships between each of our organisms by examining their shared heritable characteristics/traits. Organisms that share a greater number of traits with each other are likely more closely related. By making a checklist of which traits are present or absent in each of our organisms, we can determine which features likely evolved early in their ancestry and became passed down to each subsequent lineage, versus traits that evolved more recently and help to distinguish a separate lineage. Traits that evolved that differentiate new lineages from their ancestral groups are known as **derived** traits, whereas **ancestral** traits are those that are inherited from more distant ancestors.

https://www.khanacademy.org/science/biology/her/tree-of-life/a/phylogenetic-trees
https://www.khanacademy.org/science/biology/her/tree-of-life/a/building-an-evolutionary-tree

https://evolution.berkeley.edu/evolibrary/article/0_0_0/evotrees_intro