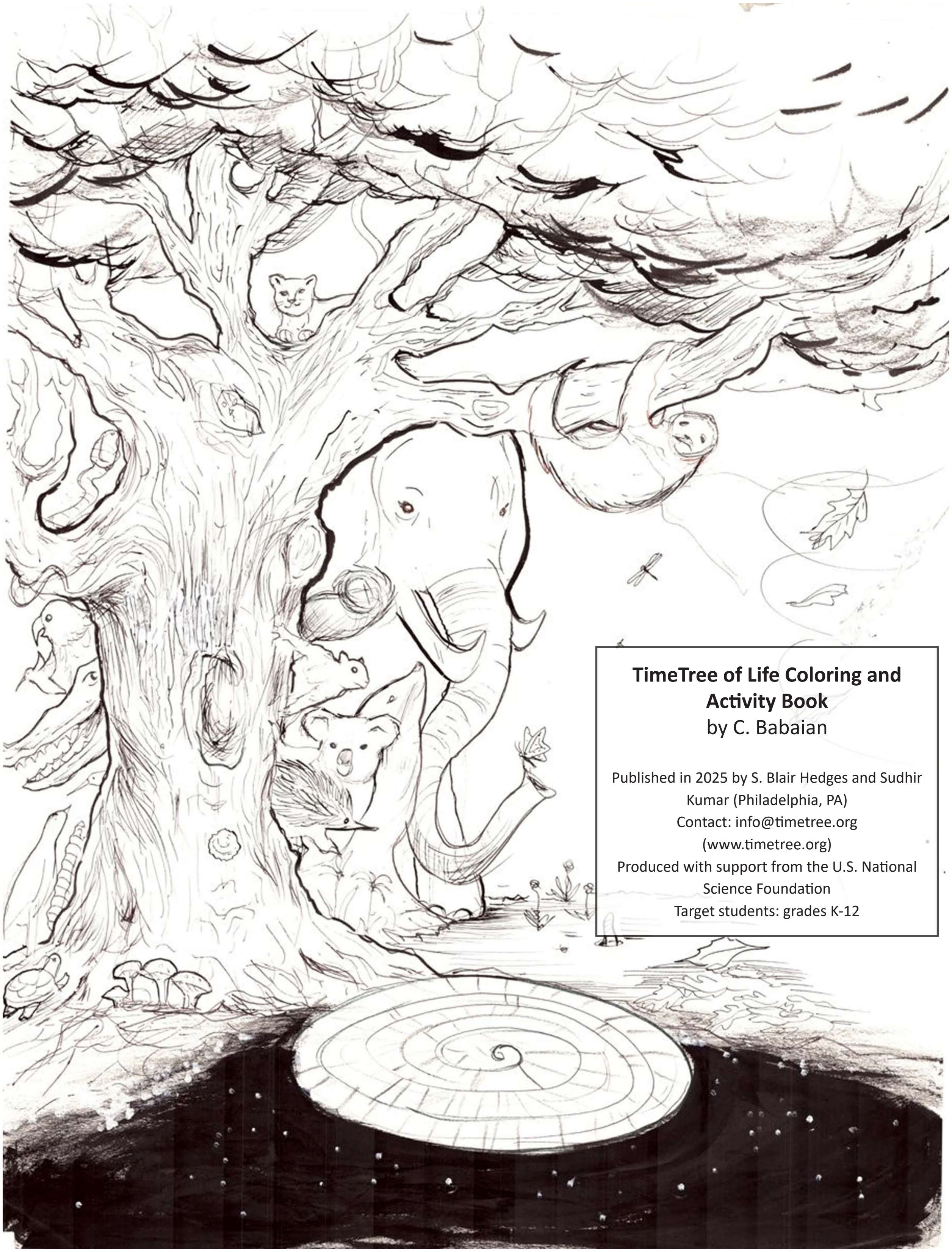

Timetree
of LIFE
Coloring
and Activity
Book



TimeTree of Life Coloring and Activity Book

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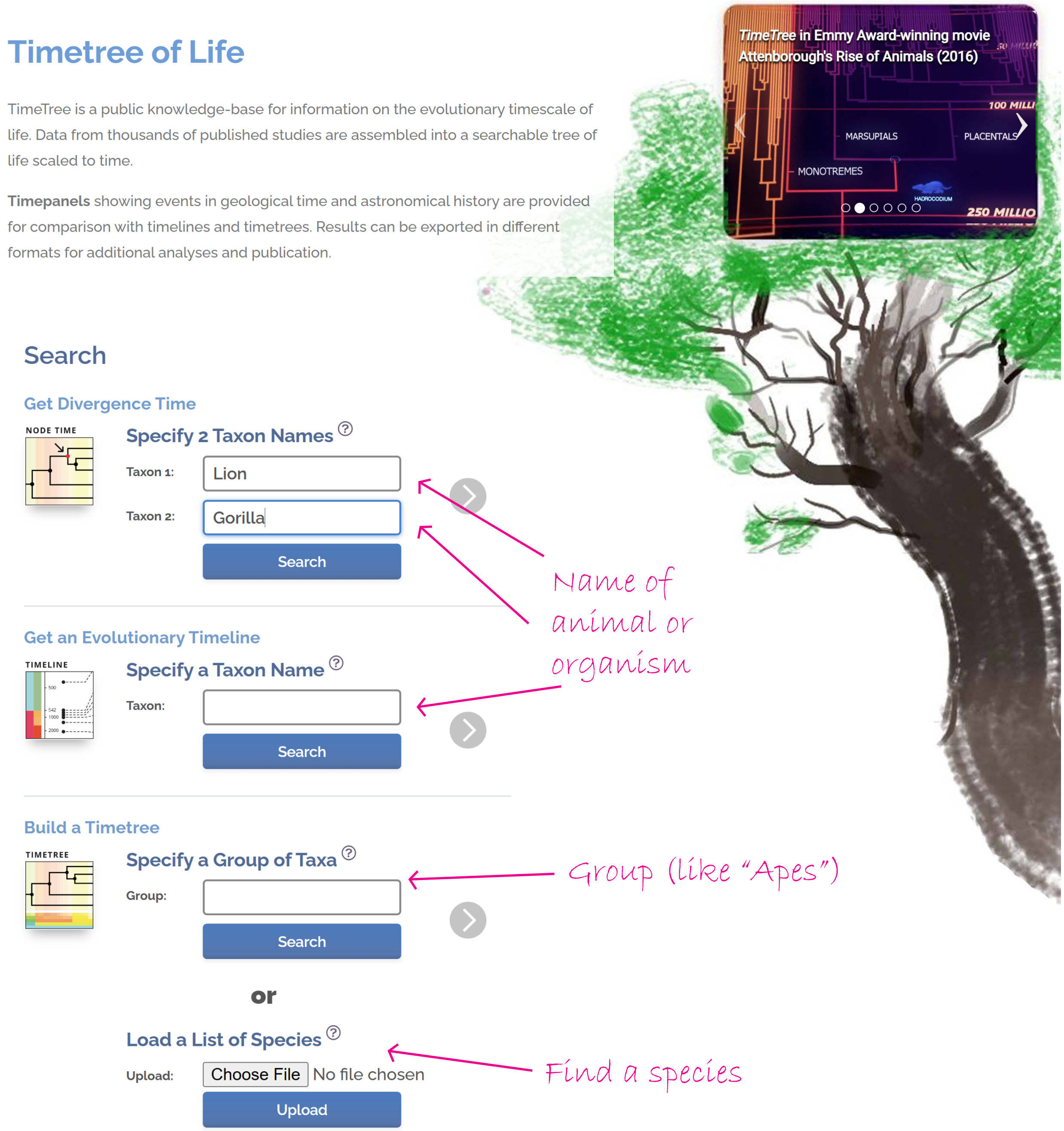
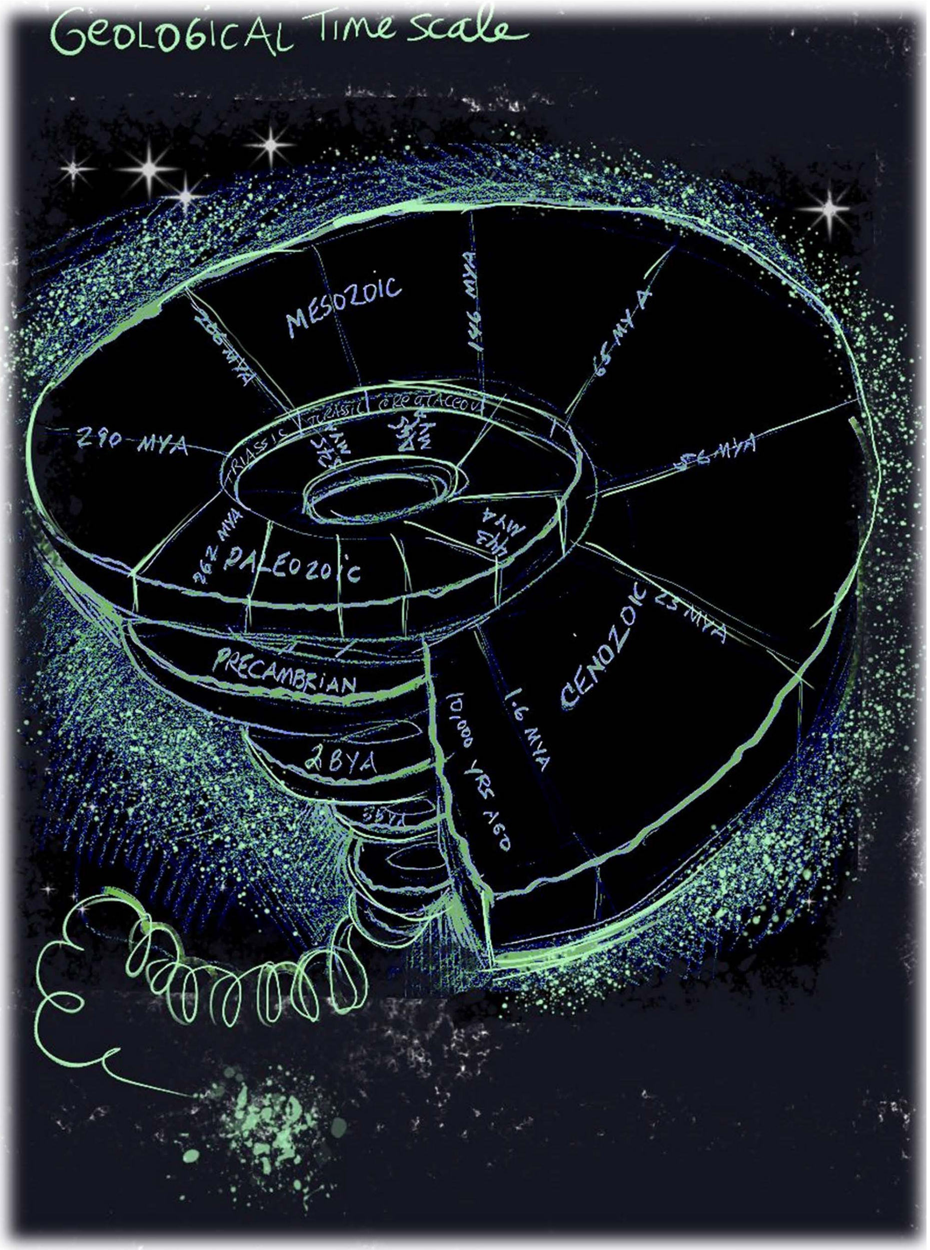


When you visit the website www.timetree.org, you will see this page.

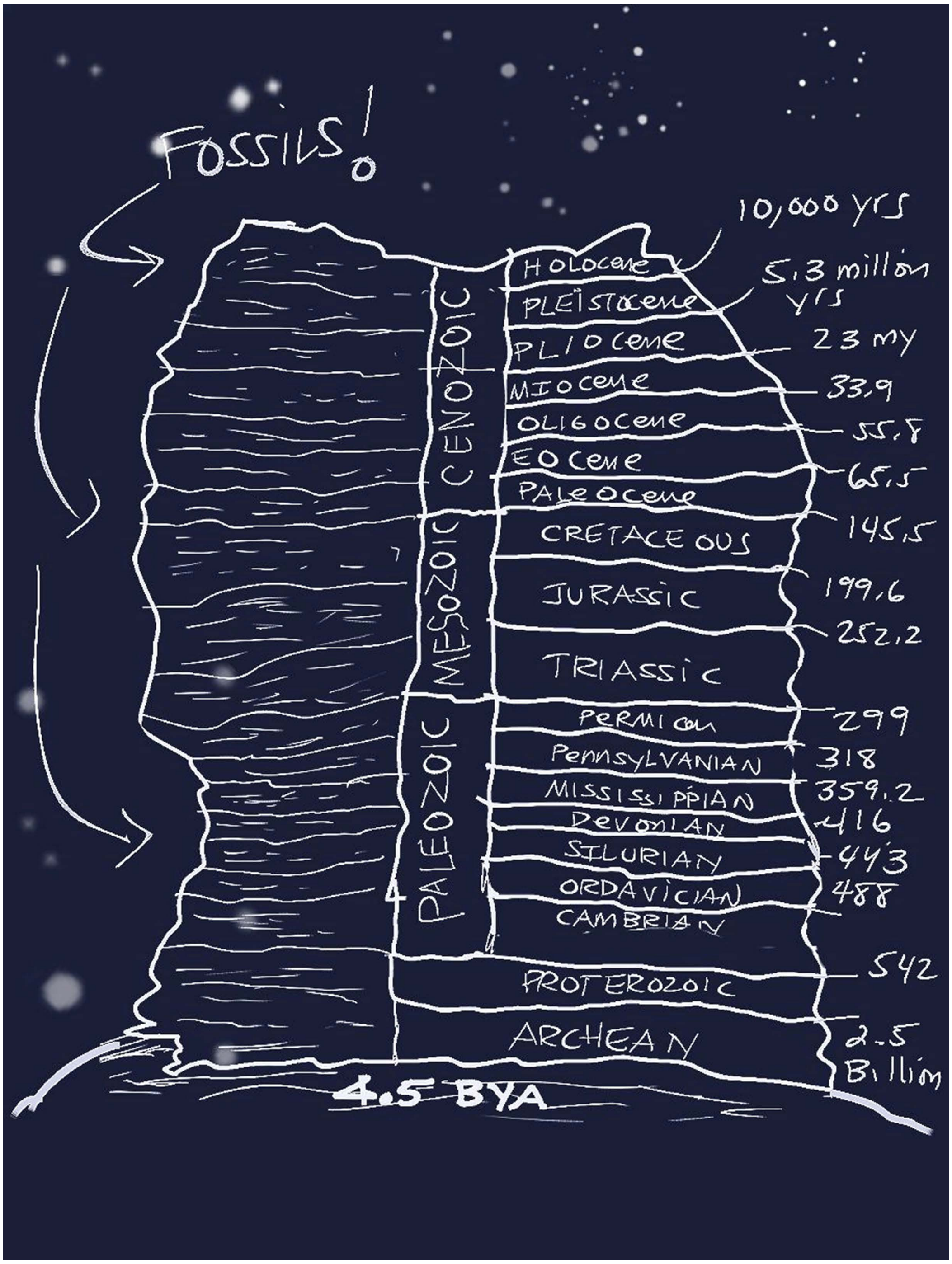
This page is where you can enter the animals of interest and find out evolutionary information about them, such as when they diverged.

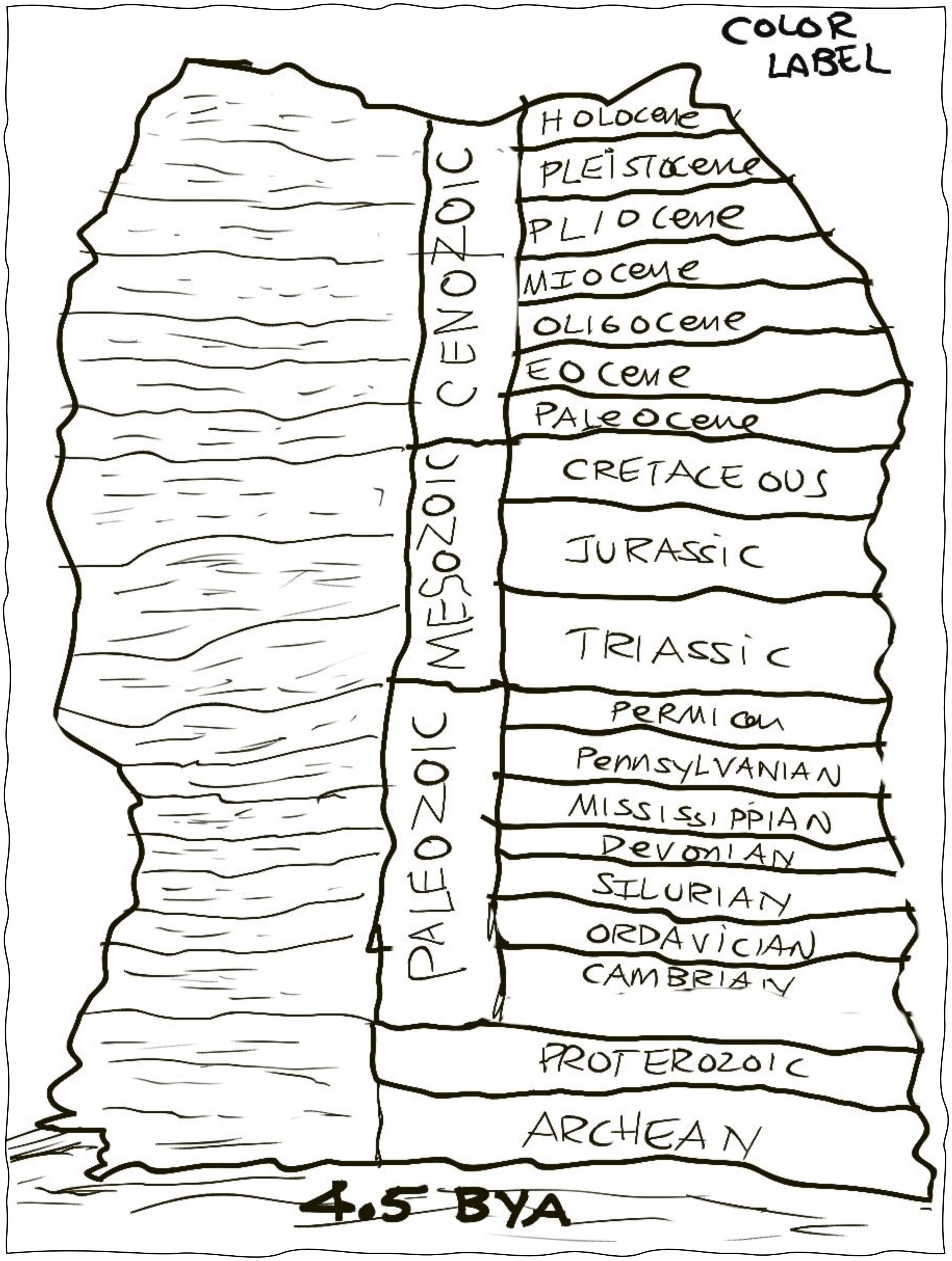
A divergence time is the evolutionary time when two organisms became different species. See the next page!



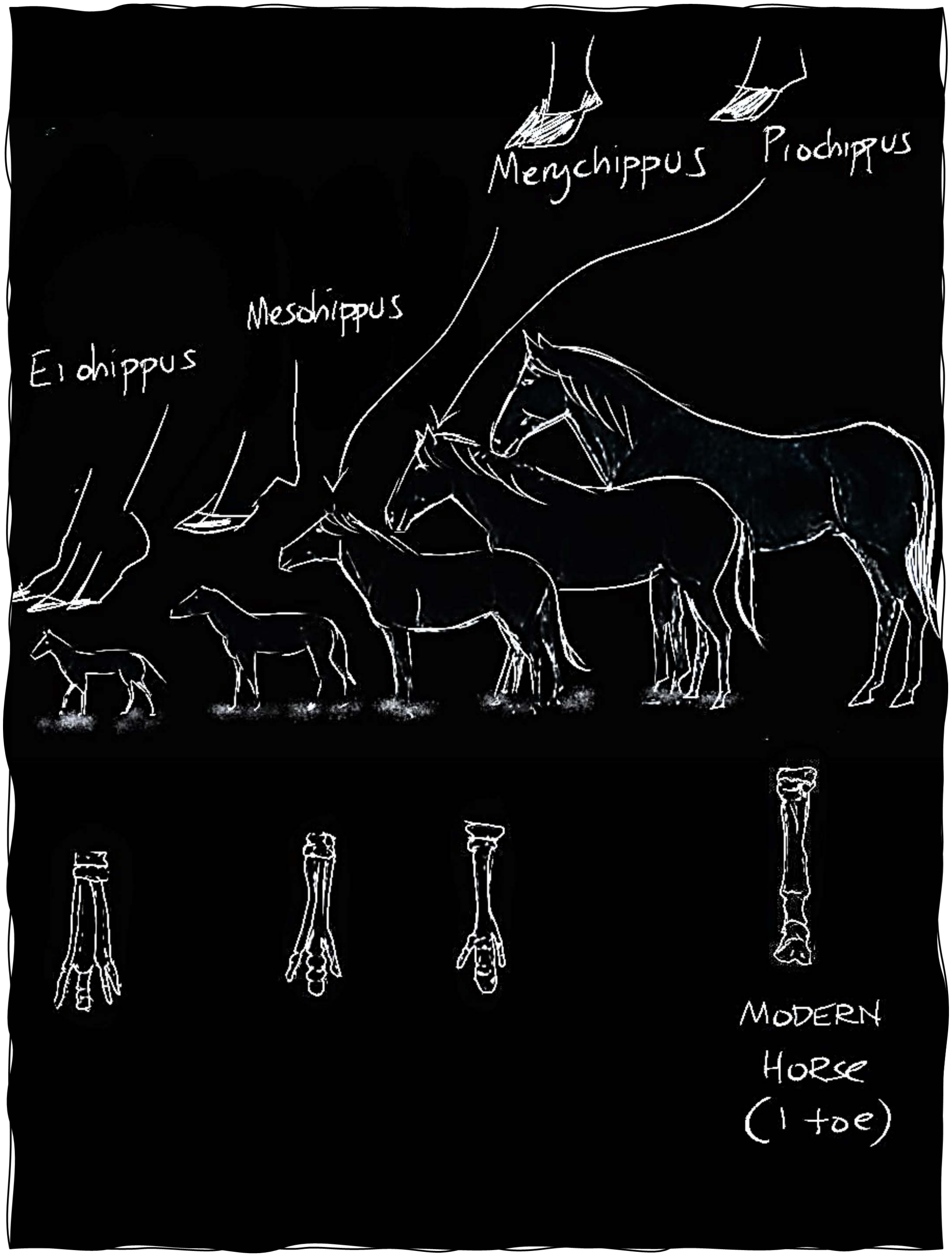
This is an evolutionary spiral of time. We don't know if it really looks like this, since millions and billions of years are hard to see. But, we make can make pictures that represent what they might look like. Here you see our current time, the CENOZOIC, at the edge, followed by the next most recent section of long evolutionary time known as the MESOZOIC and then the PALEOZOIC. These are called ERAs. Notice we are talking about hundreds of millions of years! A divergence time may go far back in time, or it may be more recent. Each of these large time frames is made of smaller units of time called a PERIOD. An even smaller section of time inside the PERIOD is called an EPOCH.

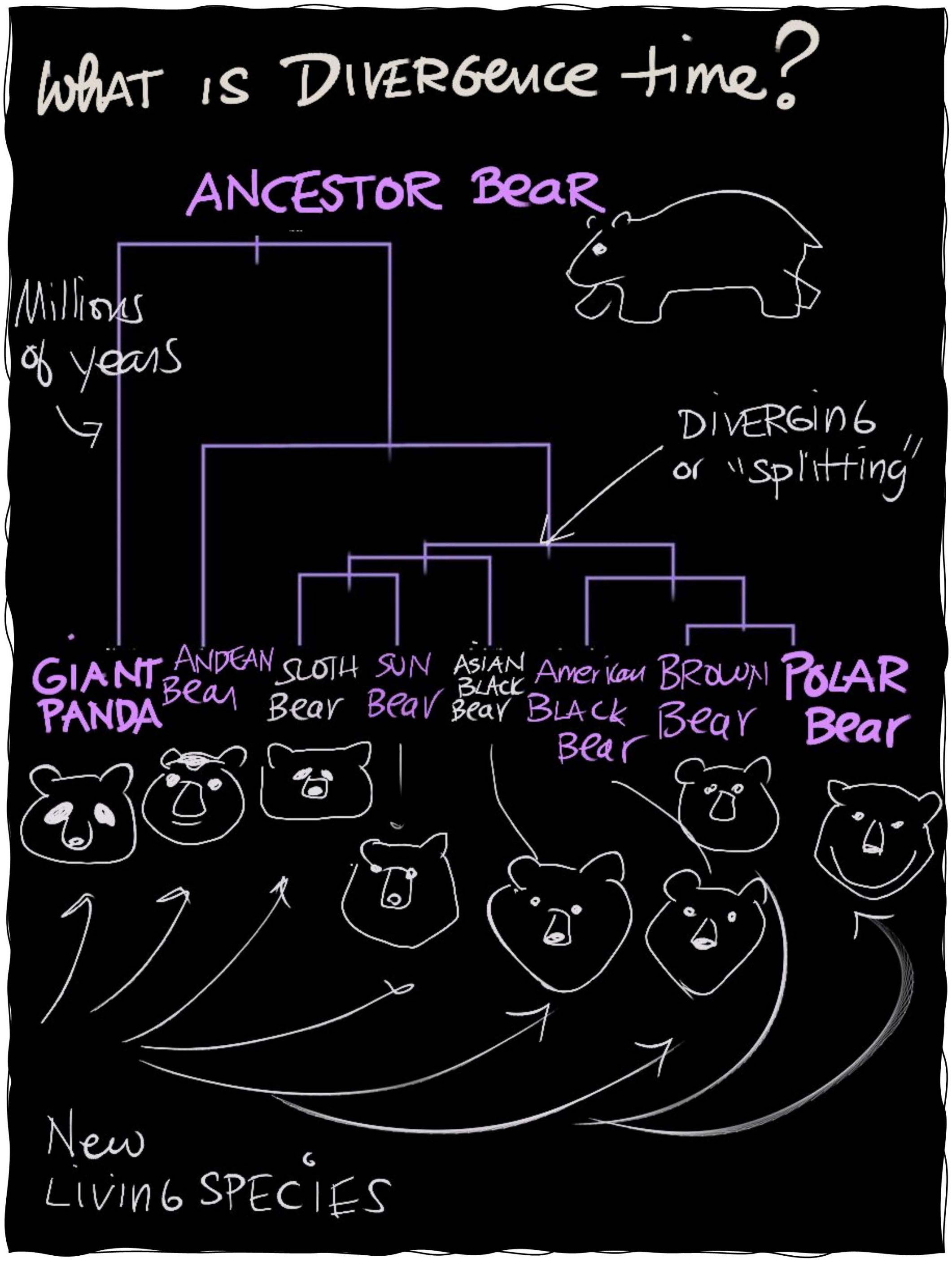
This is also a representation of what geological time looks like. This is a picure of layers of rocks, called strata. The most recent rocks are at the top and the oldest are at the bottom. Time moves in an arrow or in a linear way. We are sitting at the top of the earth's rock strata because we are in the present. In a million years where do you think humans will be?




COLOR
LABEL
HOLOCENE
PLEISTOCENE
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
PALEOCENE
CENOZOIC
CRETACEOUS
JURASSIC
TRIASSIC
MESOZOIC
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDAVICIAN
CAMBRIAN
PALEOZOIC
PROTEROZOIC
ARCHEAN
4.5 BYA

In the geological time scale, organisms, which contain much variation, are exposed to many pressures and environments. If they survive, they pass their traits on. Here is a little picture of the evolution of the horse's hoof. A smaller ancestor millions of years ago had three toes. Over a long time, biological changes took place and the three toes evolved into one toe, making them better at running. Eohippus is the extinct ancestor of the modern horse.



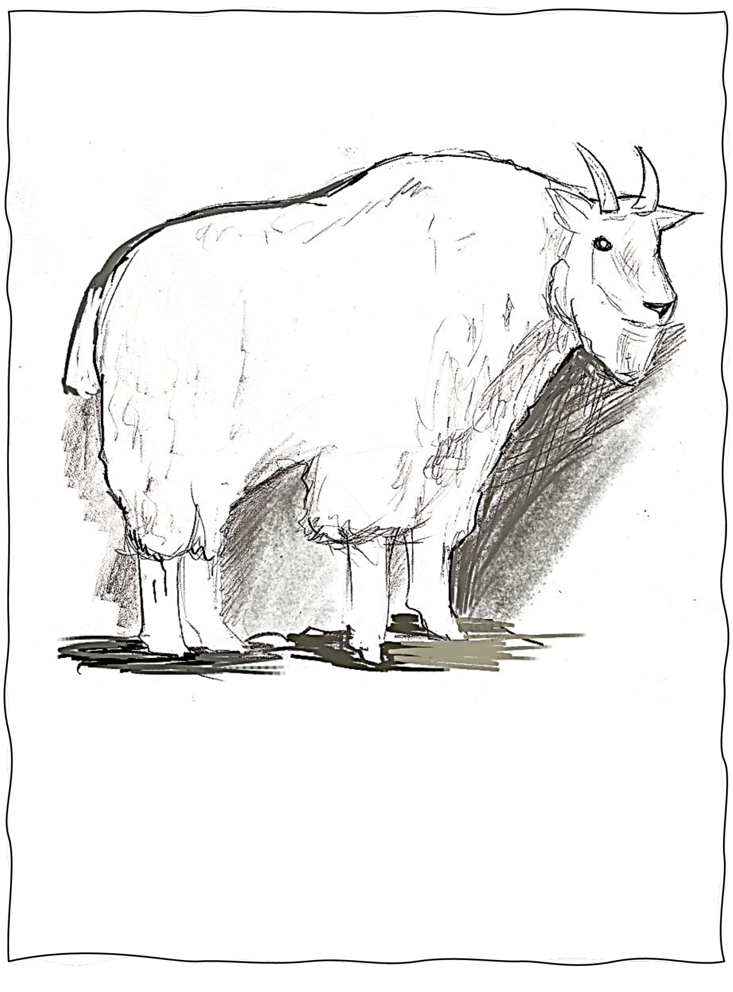


Natural selection is an evolutionary concept involving change. Differences, also known as variation, work with natural selection. This idea is known as "survival of the fittest." Think about that idea. What do you think it means? Organisms that are more adapted to their environment are more likely to survive and pass on their genes. Over time they diverge, or evolve apart. In this picture, we see an ancestral bear, which had a lot of variation. It ended up diverging into a variety of different types of bears from pandas to polar bears.

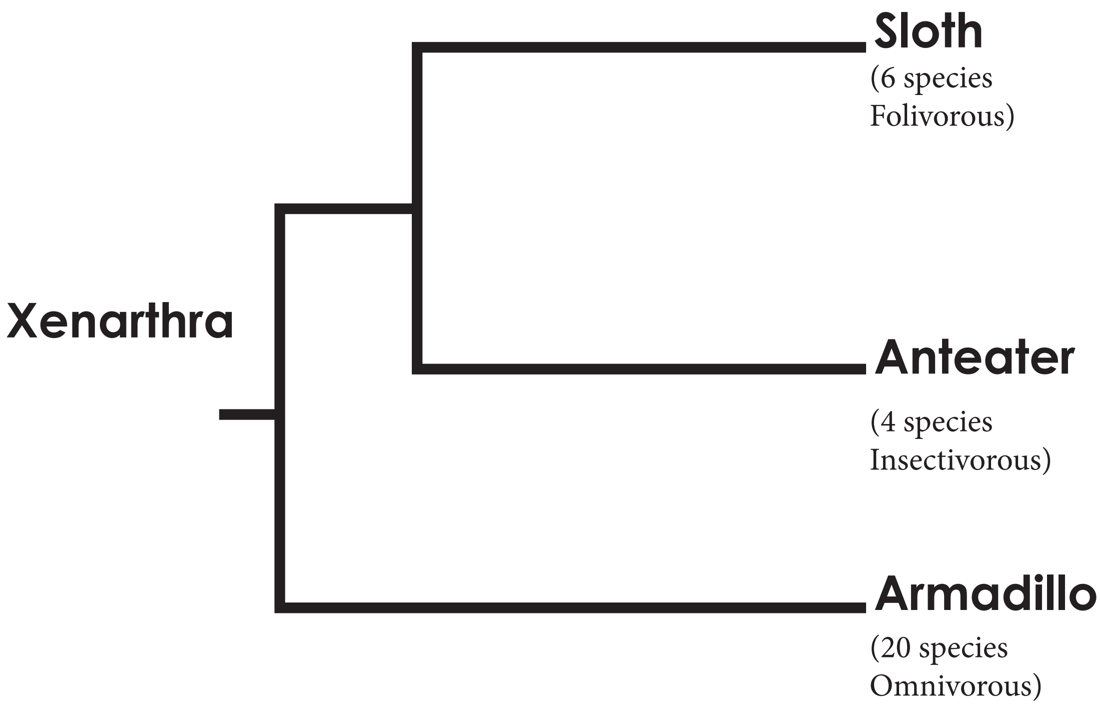
What is a scientific name?

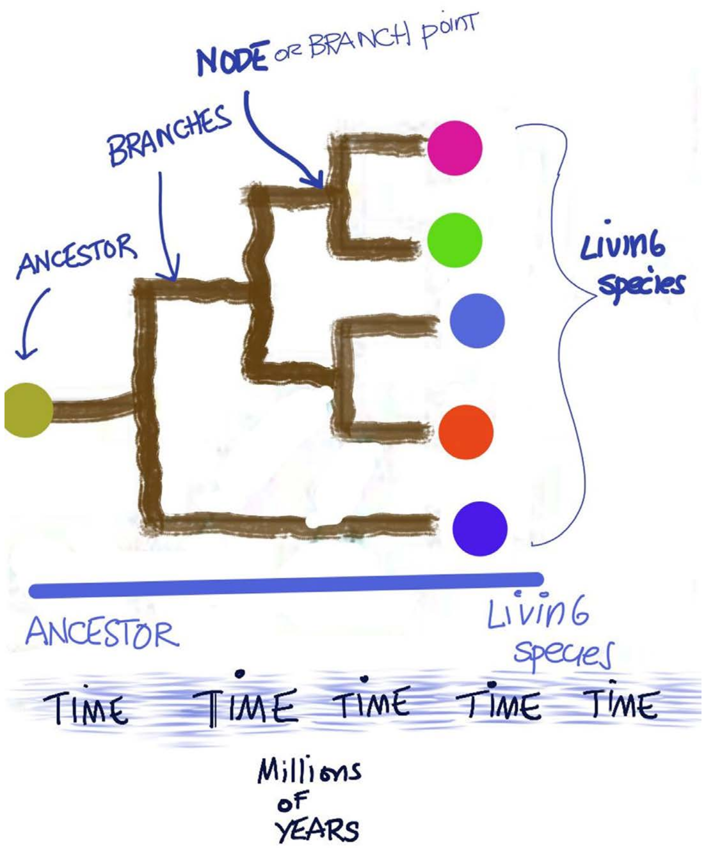
This is a Mountain Goat, also known as the "Rocky Mountain Goat." Like all species, it has a general name and a scientific name. The scientific name is in Latin, and is made up of the genus and species of the organism. The genus and species help put all the organisms into categories. For the Rocky Mountain Goat, that name is *Oreamnos americanus.*

This beautiful goat lives and climbs among the rocks and has special cloven hooves and other adaptations for climbing. This goat is the only one of that genus still alive from the Pleistocene! The scientific name gives a species a unique name. In Timetree, sometimes you will have to use the scientific name if the common name doesn't work. Try searching "mountain goat" and "*Oreamnos americanus*" and compare its divergence time with just "goat" to see what you get.



Here is a phylogenetic tree for a clade called Xenarthra, made of sloths, anteaters, and armadillos.





Label the tree above.

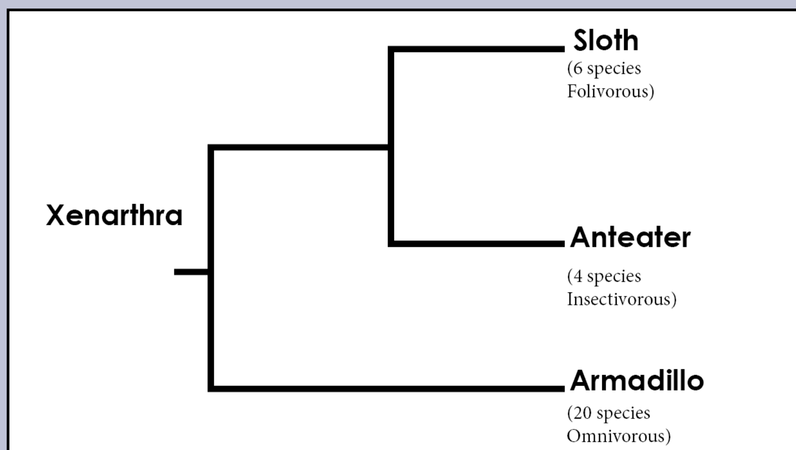
Who is the ancestor?

Who are the descendants?

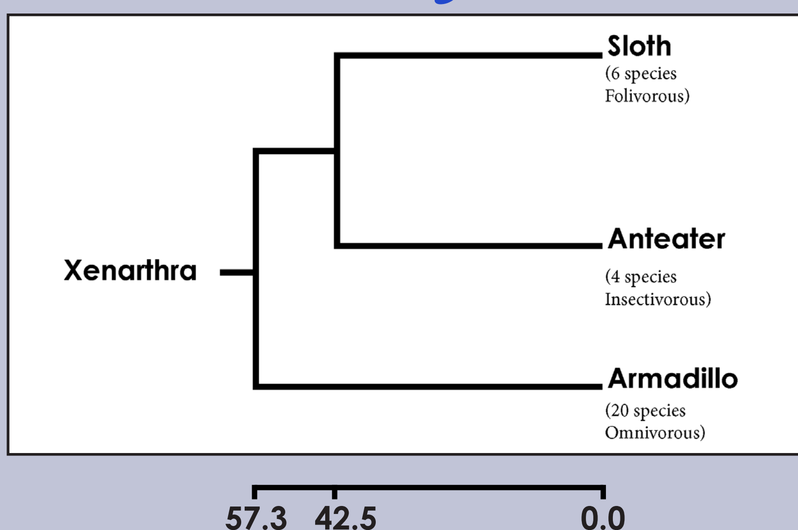
What are the branches?

Where are the nodes of divergence?

Phylogenetic Tree of Sloths



Timetree of Sloths



Time Scale (in millions of years ago)

What kinds of questions can you ask the Timetree time machine?

Let's try it out. Compare the divergence times of two mammals who look like each other, but one lives in the wild and the other maybe sleeps on your bed or head.

Colors: Tan & Brown

You are comparing a Sand Cat with a Domestic Cat.

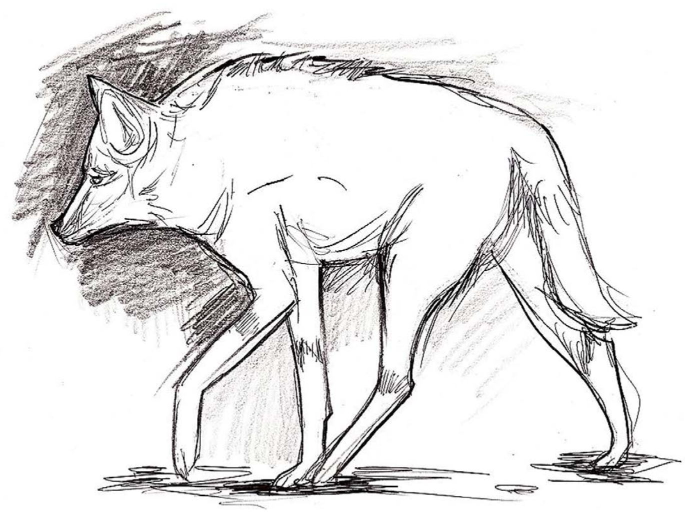
The divergence time is_____________________________

What can you find out about both cats?

What habitat do you find the Sand Cat in?

Let us do the same for dogs.
Compare a domestic dog with a Maned Wolf.

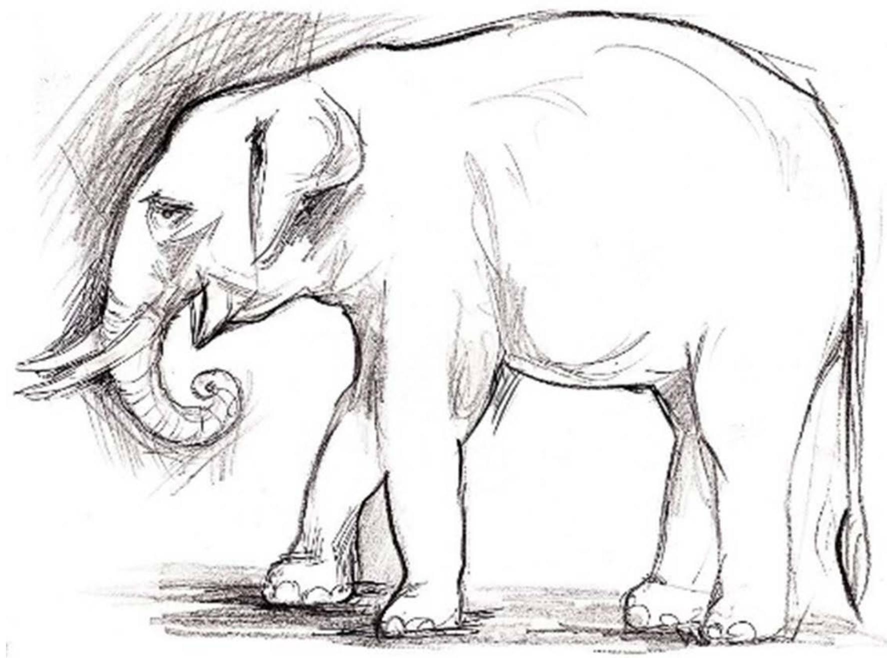
Colors: Rust, Brown, Dark Brown

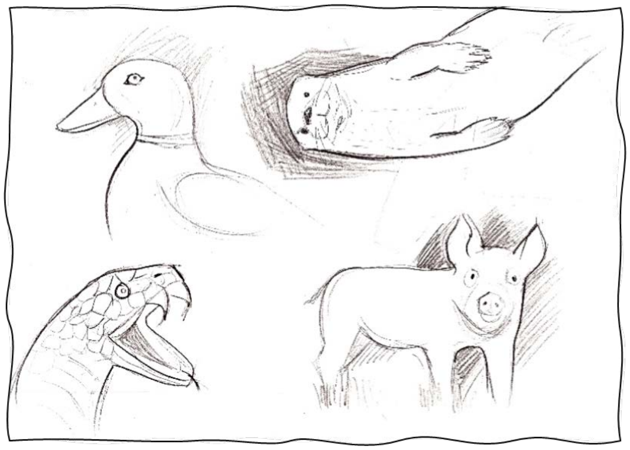


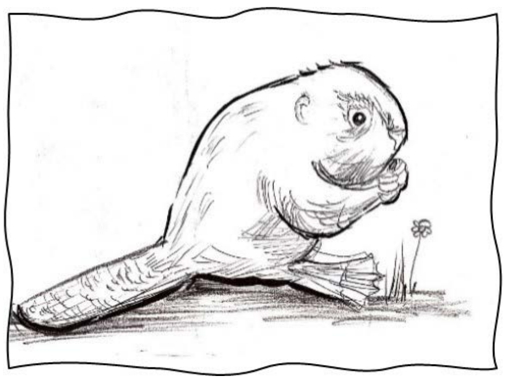
Colors: Black, Brown, Tan

Here are two animals that are very different in size and appearance (sort of).

One is the Indian Elephant the other is a little gofer-like mammal called a Hyrax. **Find out what their divergence time is.**







Below is an animal called a Duck-billed Platypus.

Now you might not know how to classify this animal. It's a very cute animal, but it seems to be made of different creatures.

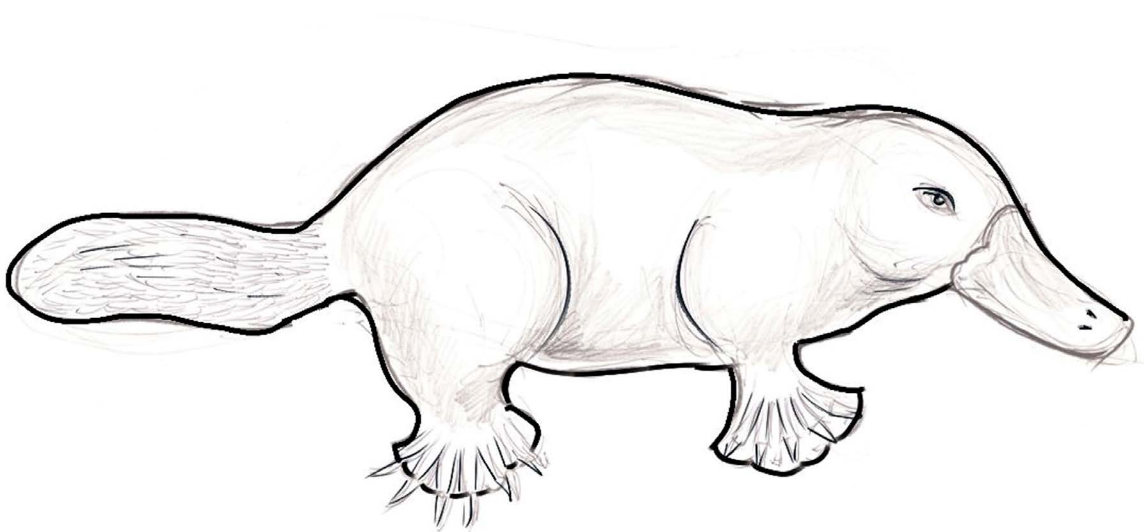
It has a mouth like a duck

Webbed feet like an otter

Fur like a beaver

And venom barbs like a rattlesnake

Search divergence times on the next page with all these animals and include a little pig too.



For a Timetree search, you will have to use the scientific name for the Duck-billed Platypus, which is : *Ornithorhynchus anatinus*

Divergence time

Duck-billed Platypus____________________Duck

Duck-billed Platypus____________________Otter

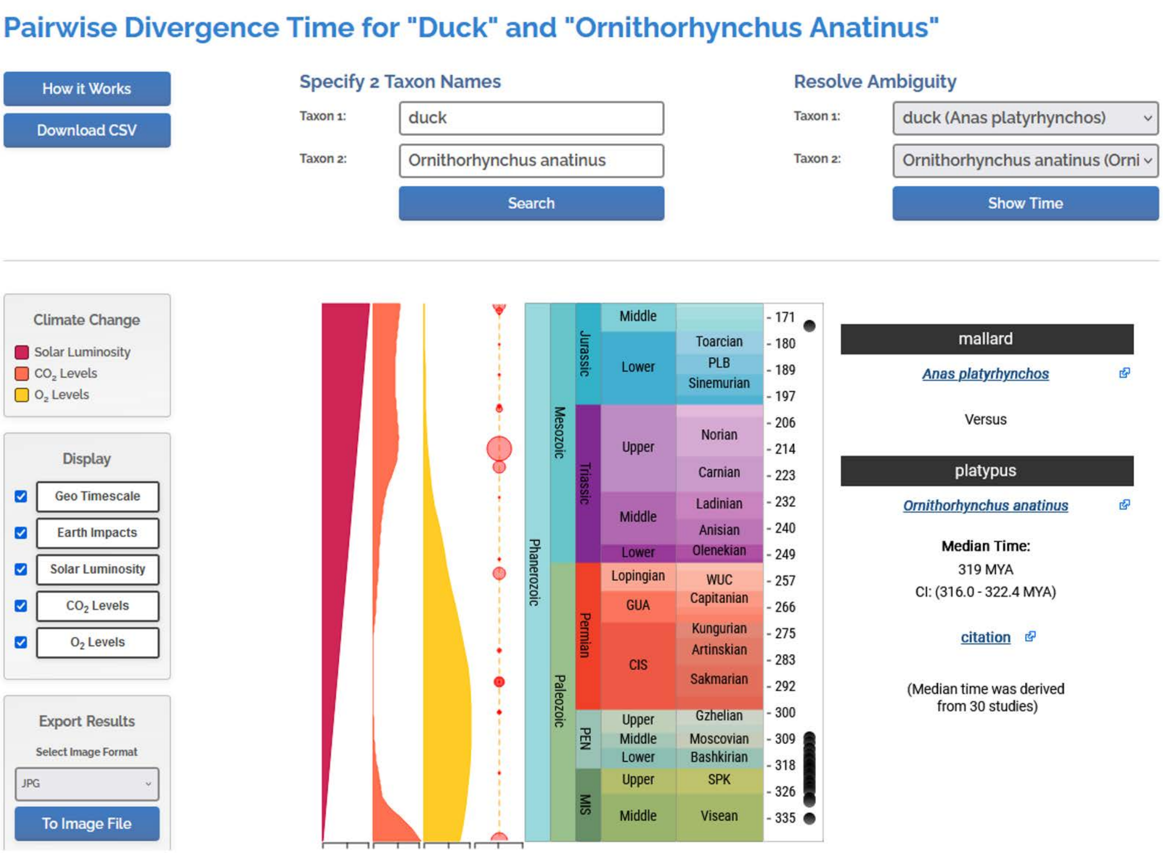
Duck-billed Platypus____________________Rattlesnake

Duck-billed Platypus____________________Beaver

Duck-billed Platypus____________________Domestic Pig

Who shows the shortest divergence time?

Who shows the longest divergence time?



Try the Mallard Duck first with the Duck-billed Platypus. This is what you should see.

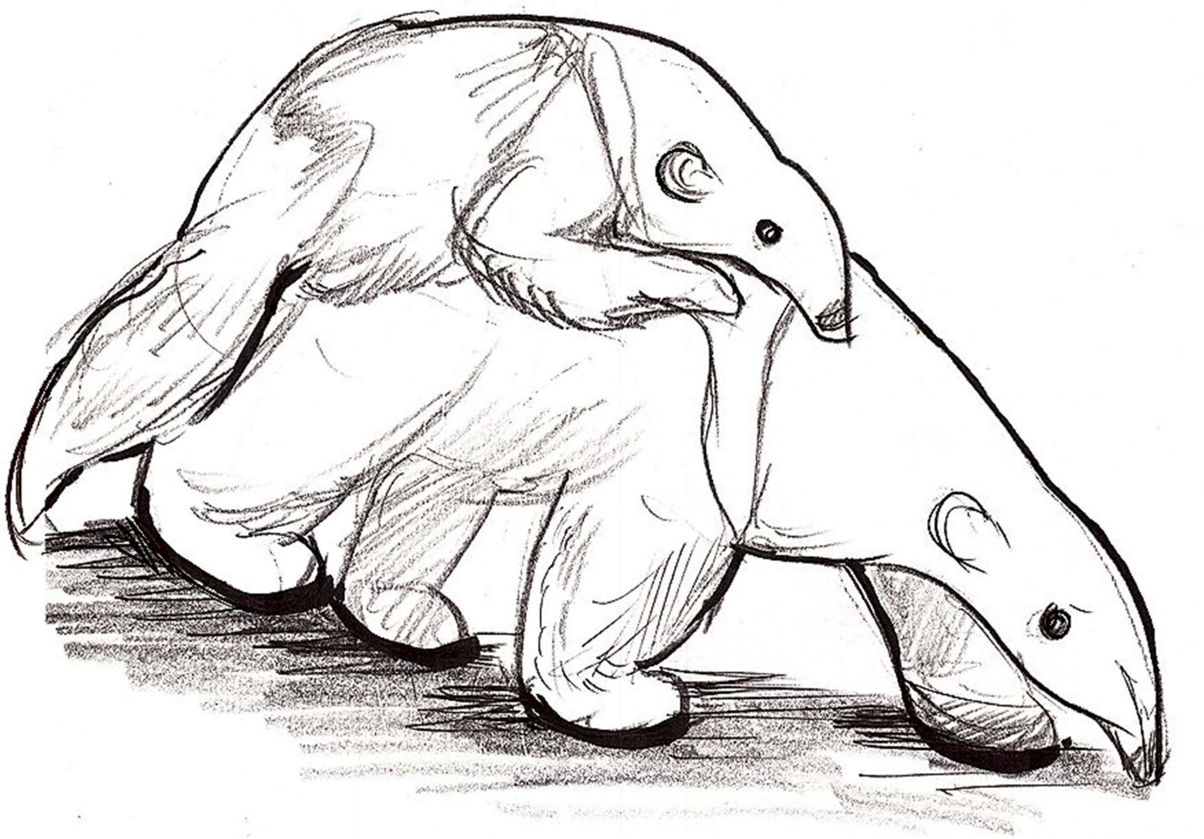
Did you ever wonder if the animals in zoos evolve? Of course they do! Most animals locked up in a zoo would probably prefer to be in their natural habitat. This is why preserving natural habitats is so important. The healthier and more intact an ecosystem is, the more habitat and homes animals have. It is up to us to not keep building over their homes. But if you do go to the zoo, you can compare the divergence times of different animals when you get back to your habitat. On the following coloring pages are some animals you might find in a zoo. Which ones do you think are most related? Fill in the scientific names first.

Colors: Cream, Light Brown

Loris
Scientific name:

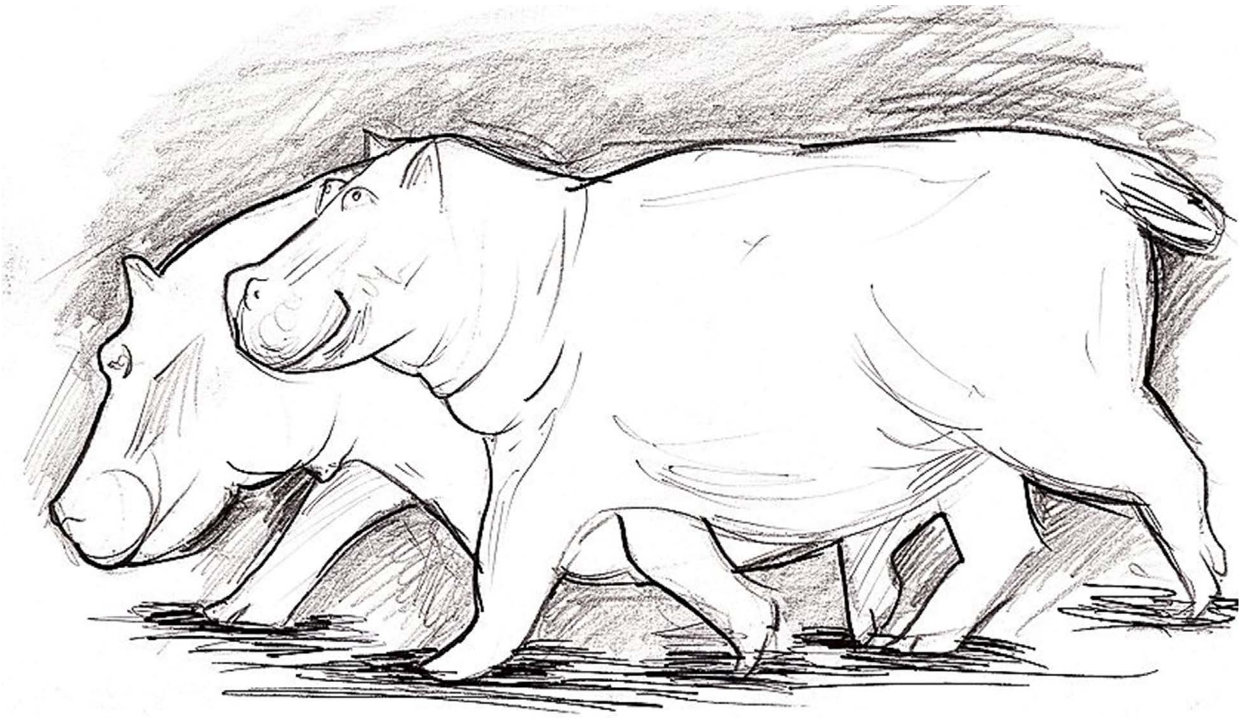
Colors: Dark and Medium Browns

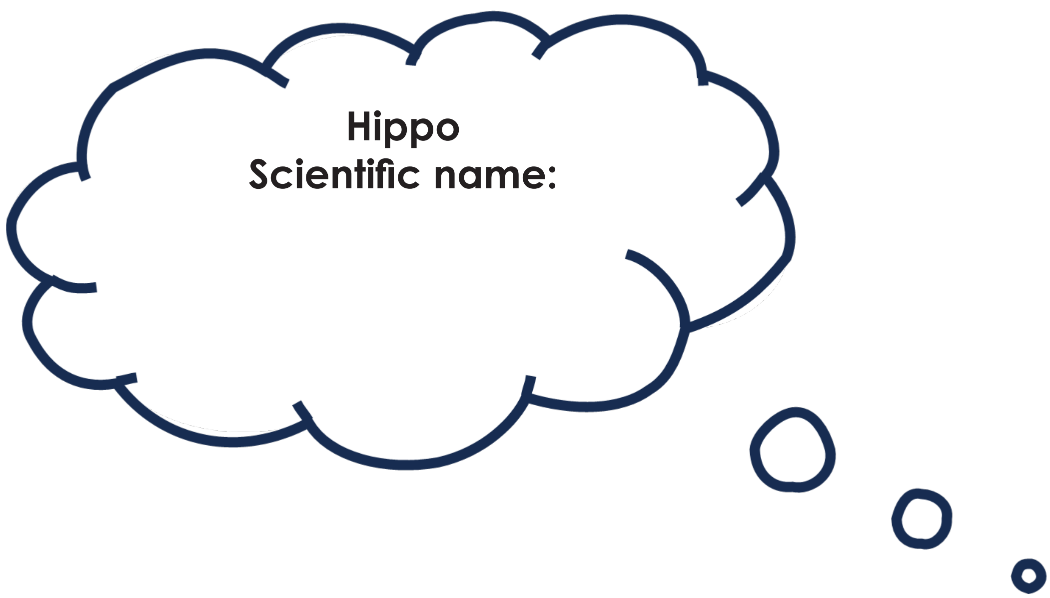
Jaguarundi
Scientific name:



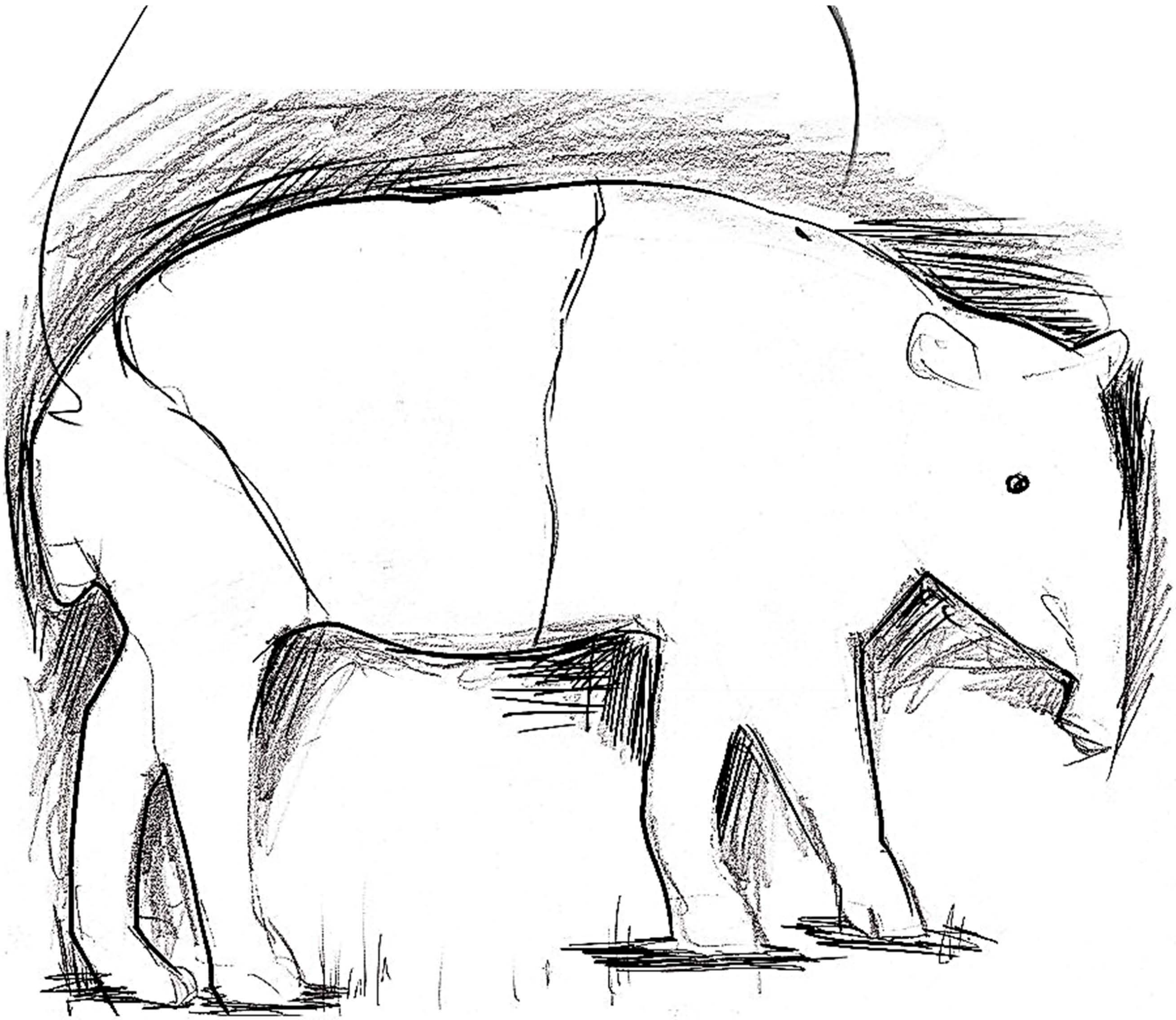
Lesser Anteater
Scientific name:

Siberian Tiger
Scientific name:



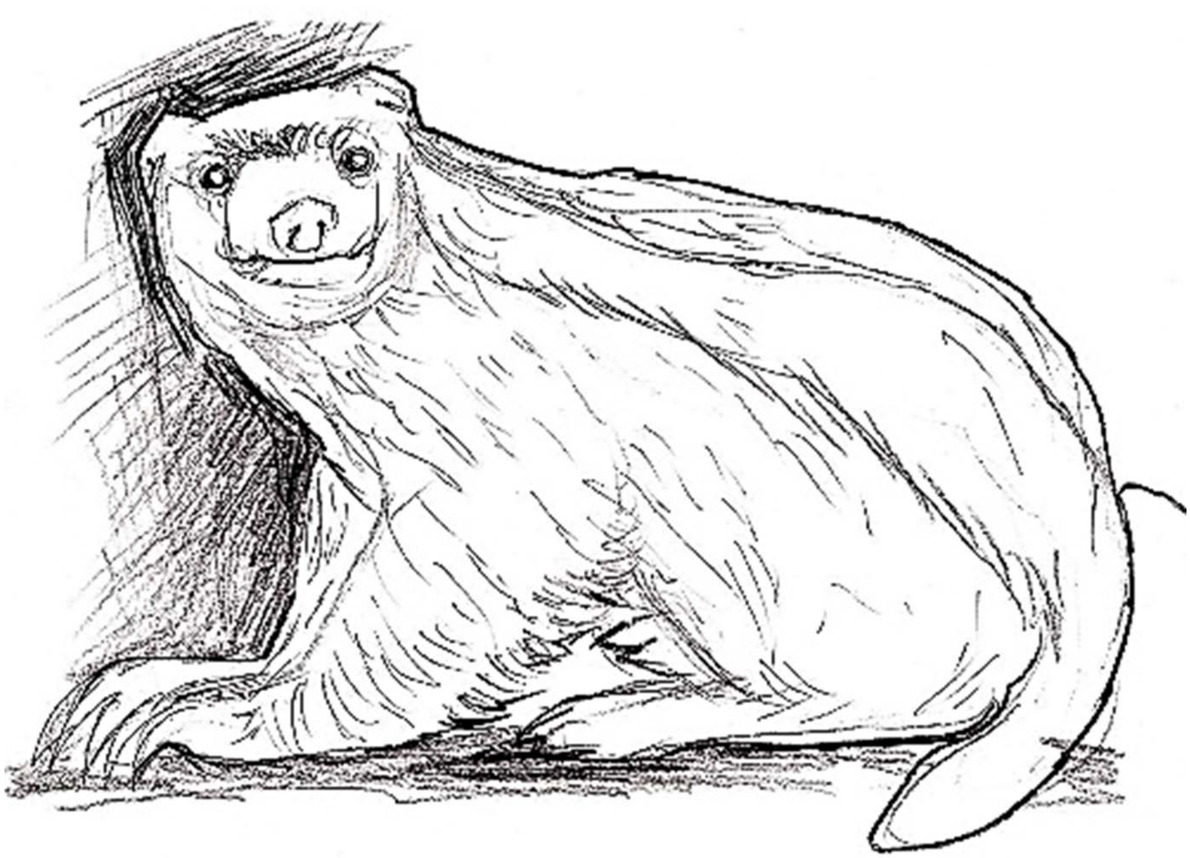

Hippo
Scientific name:

Colors: Dark Brown and White



Tapir
Scientific name:

Colors: Dark Brown, Medium Brown, and White

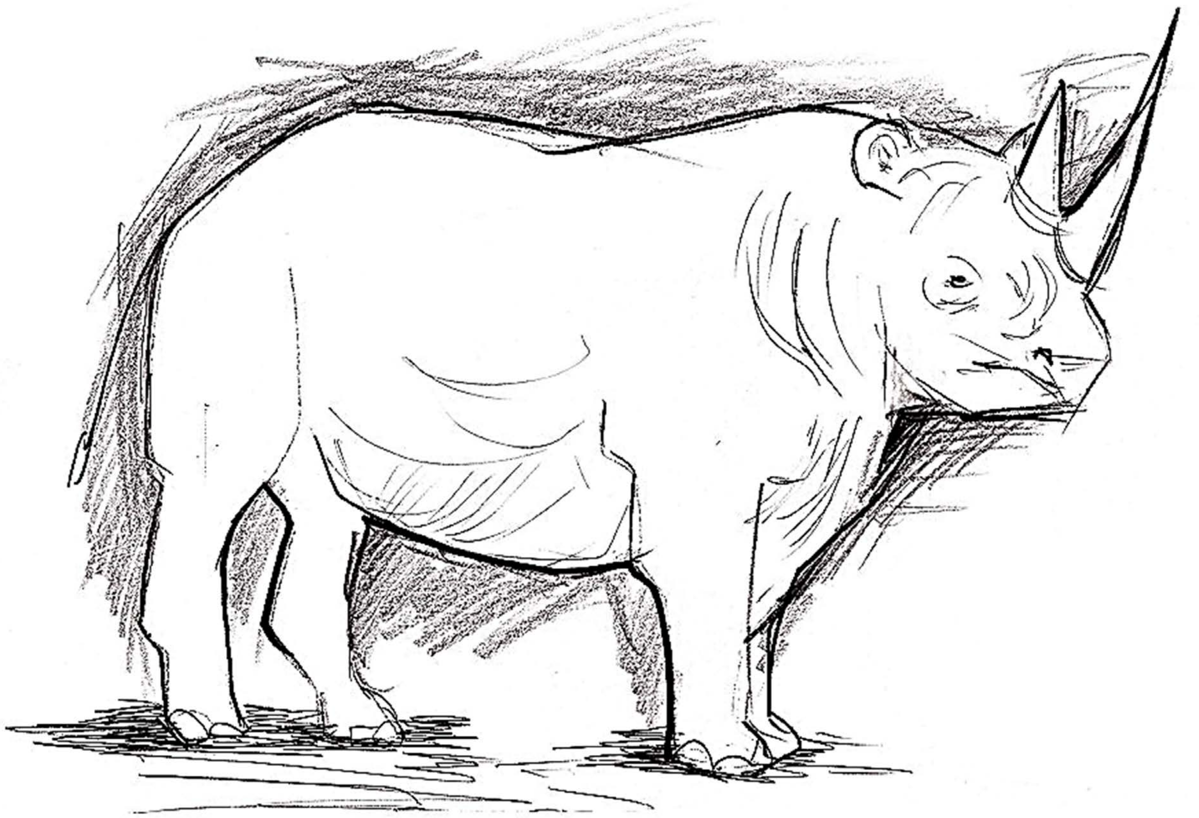


Honey Badger
Scientific name:

Sun Bear
Scientific name:

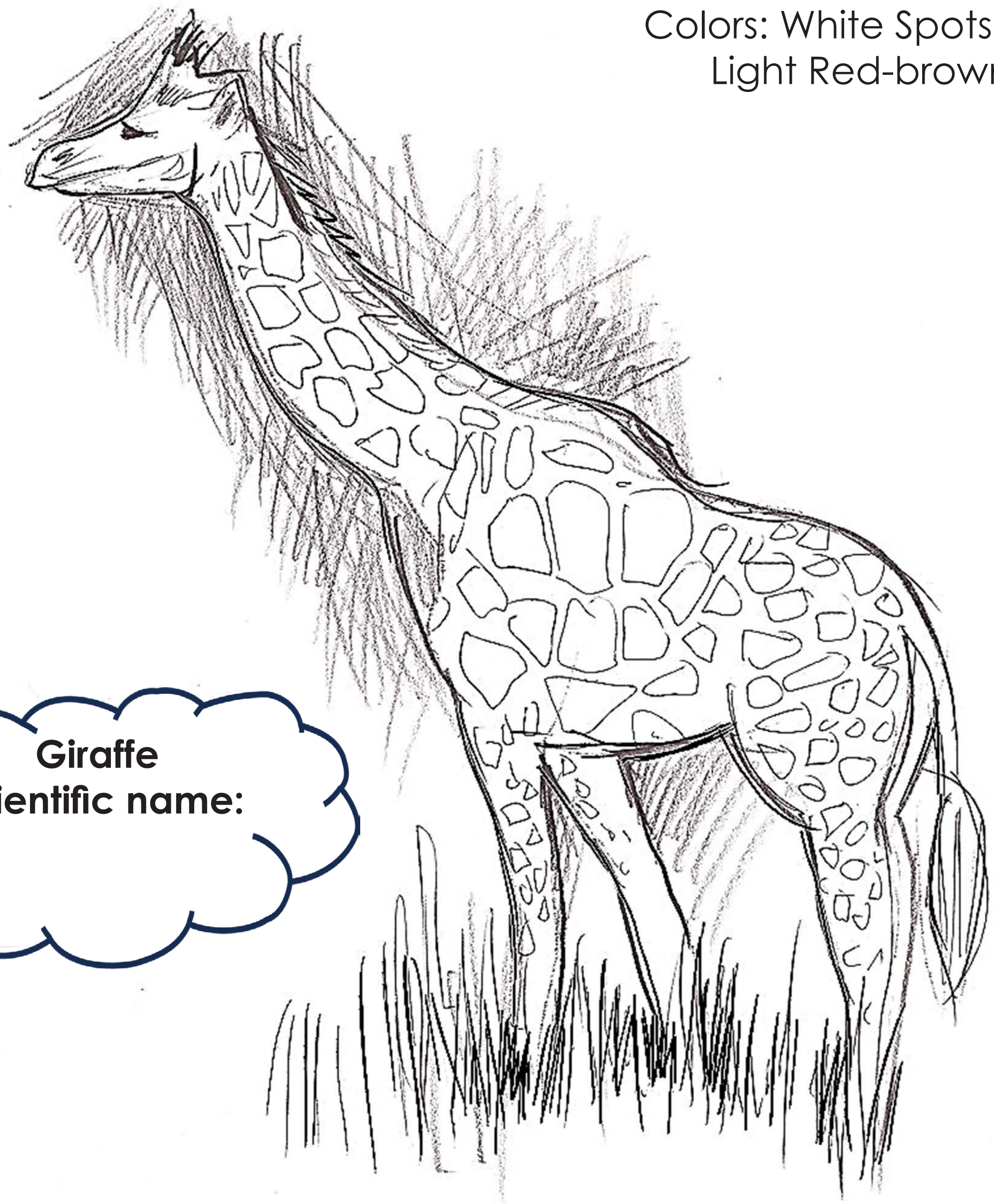
Color: Dark Browns, Brown, and White

Colors: Light Gray



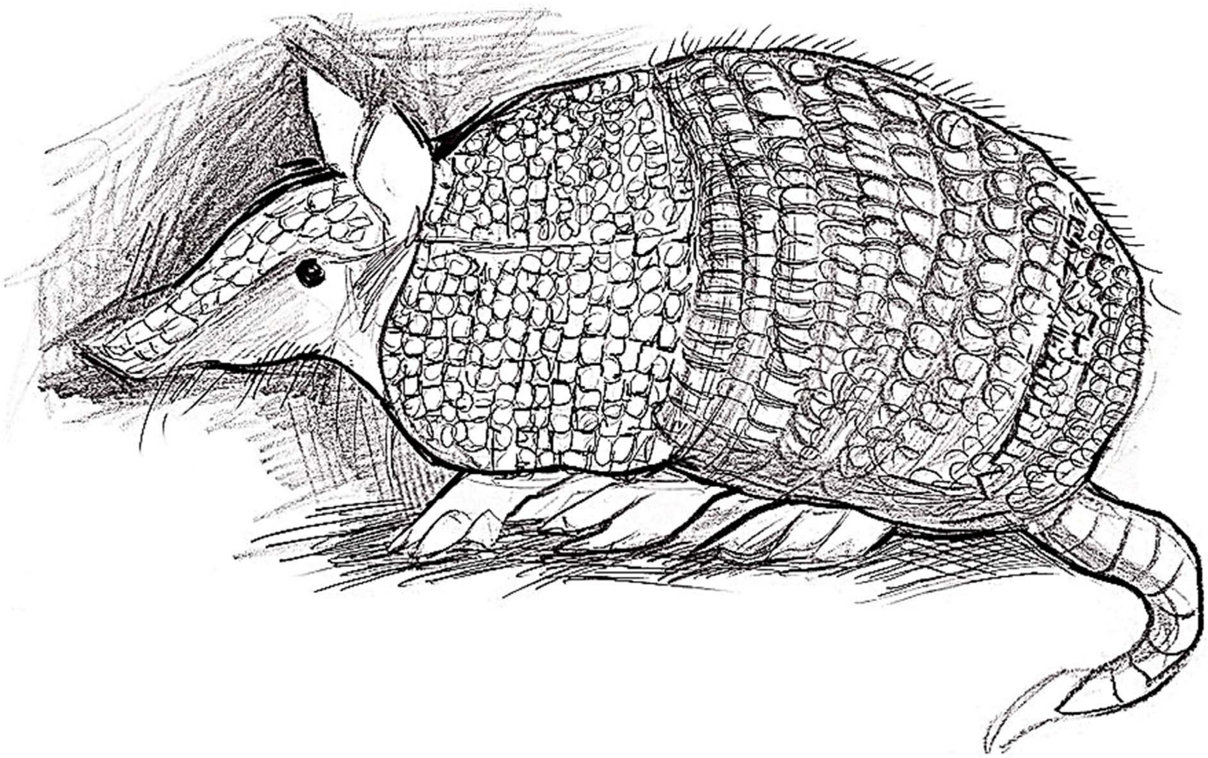
Black Rhino
Scientific name:

Colors: White Spots and
Light Red-brown

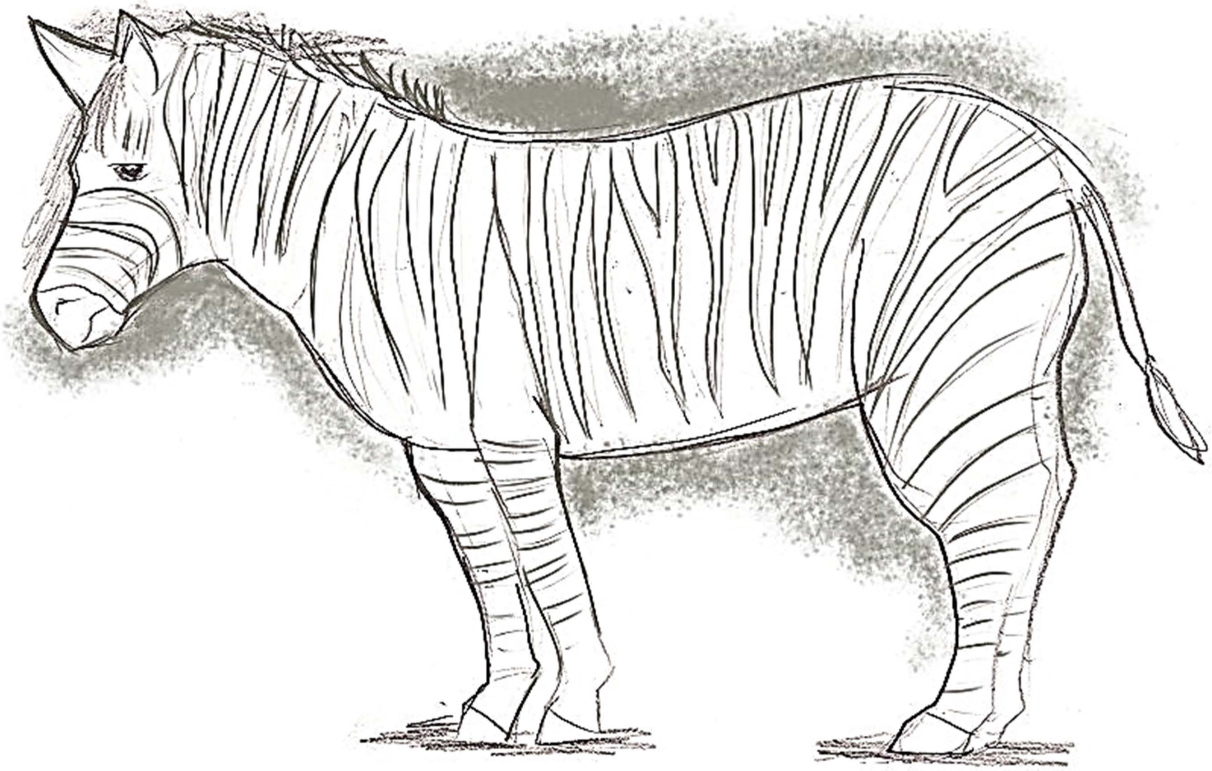


Giraffe
Scientific name:

Colors: Gray, Light Gray



Armadillo
Scientific name:



Zebra
Scientific name:

Colors: Beige and Green

Three-toed Sloth
Scientific name:

Data Sheet

Use this page to write down any animals you compared divergence times with. If you have a favorite animal include it on this page. Get together with your friends and see if you got the same divergence times, compare animals you don't think are related.

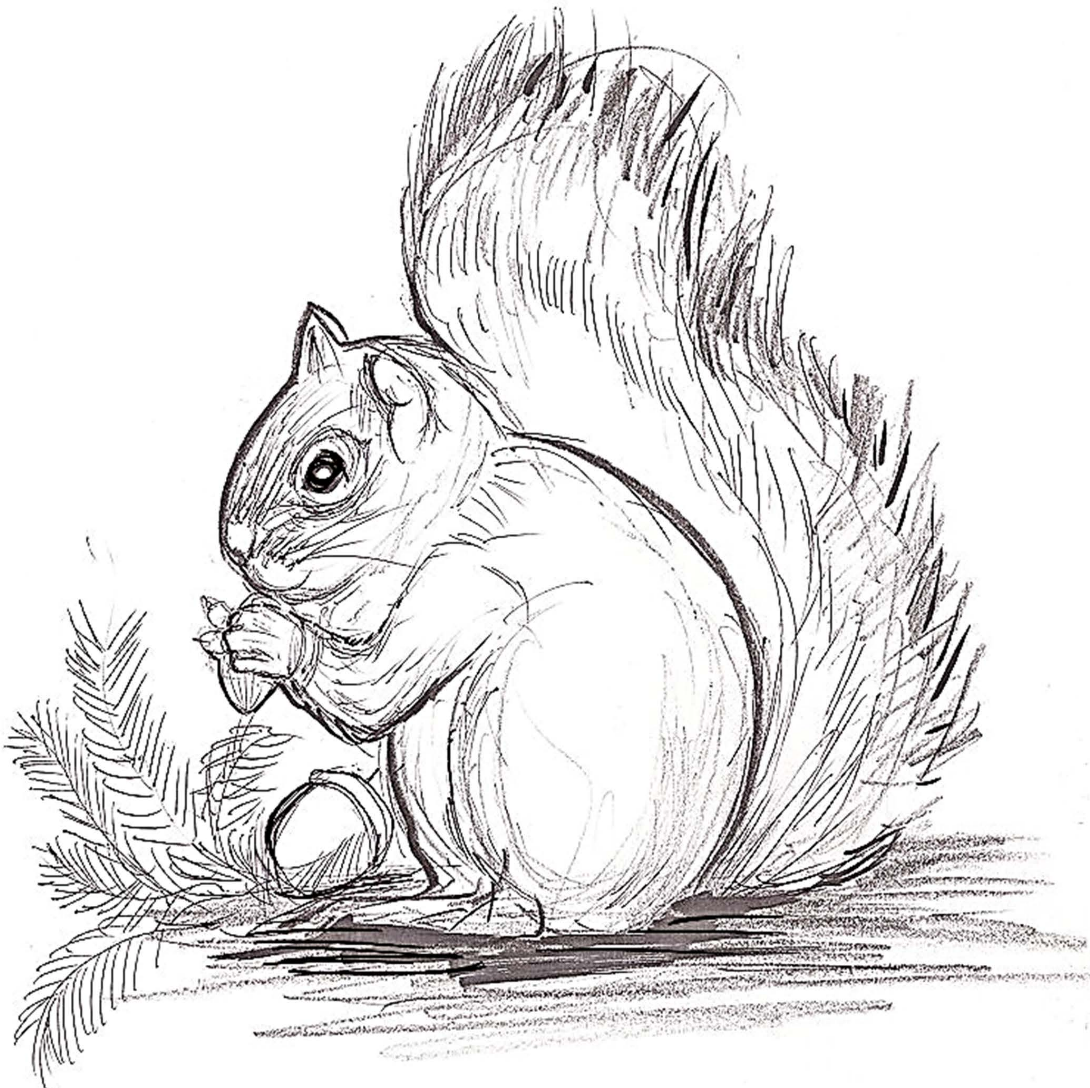
What's in your backyard? We have many homes and communities for people. But did you know that the animals were there first? We built our homes and towns over and on top of their homes and ecosystems. That means that animals like Squirrels and White-tailed Deer have been in our backyards long before there were backyards.

Compare some of the animals that might live in and around your backyard.

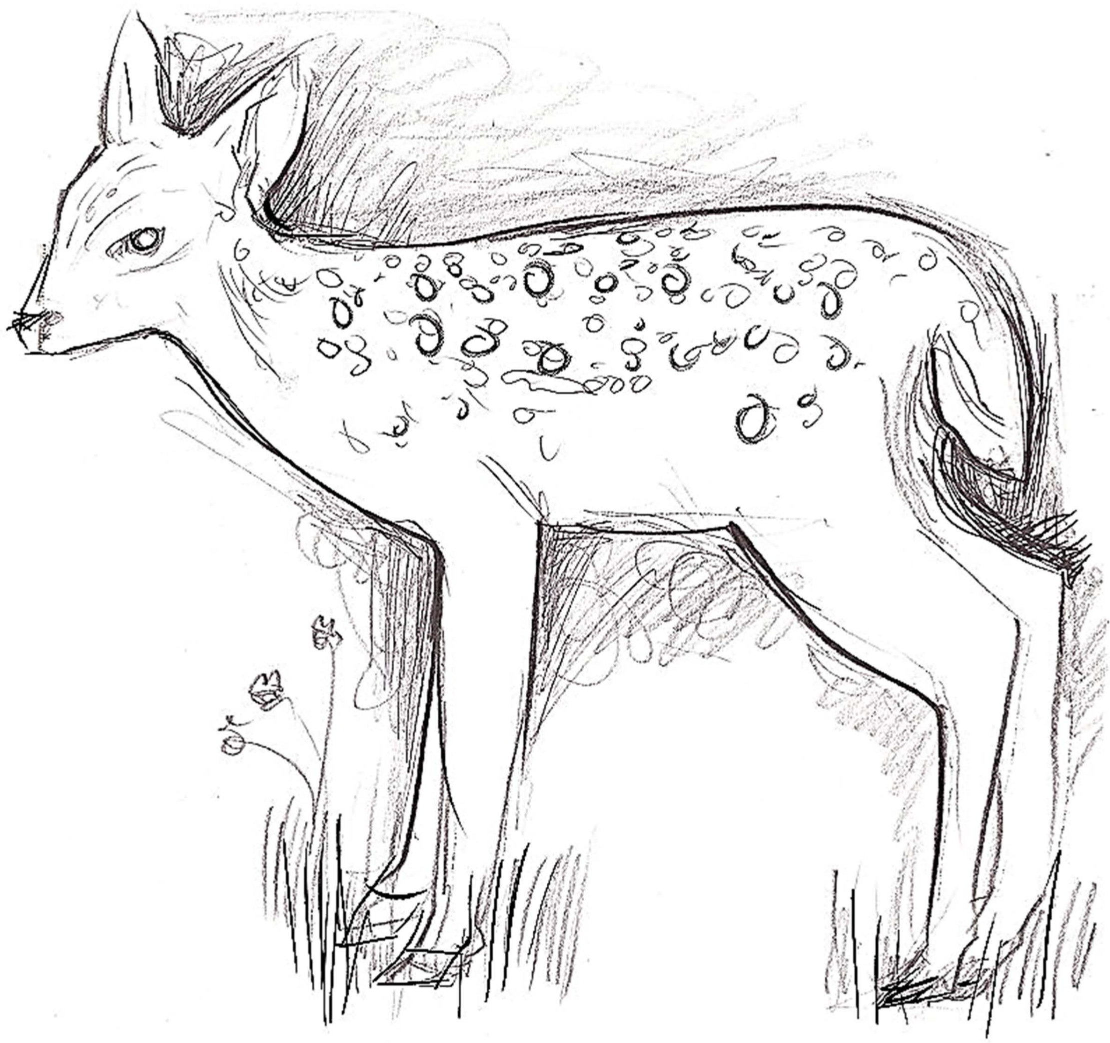
Colors: Medium Brown

Brown bat
Scientific name:

Colors: Gray and White

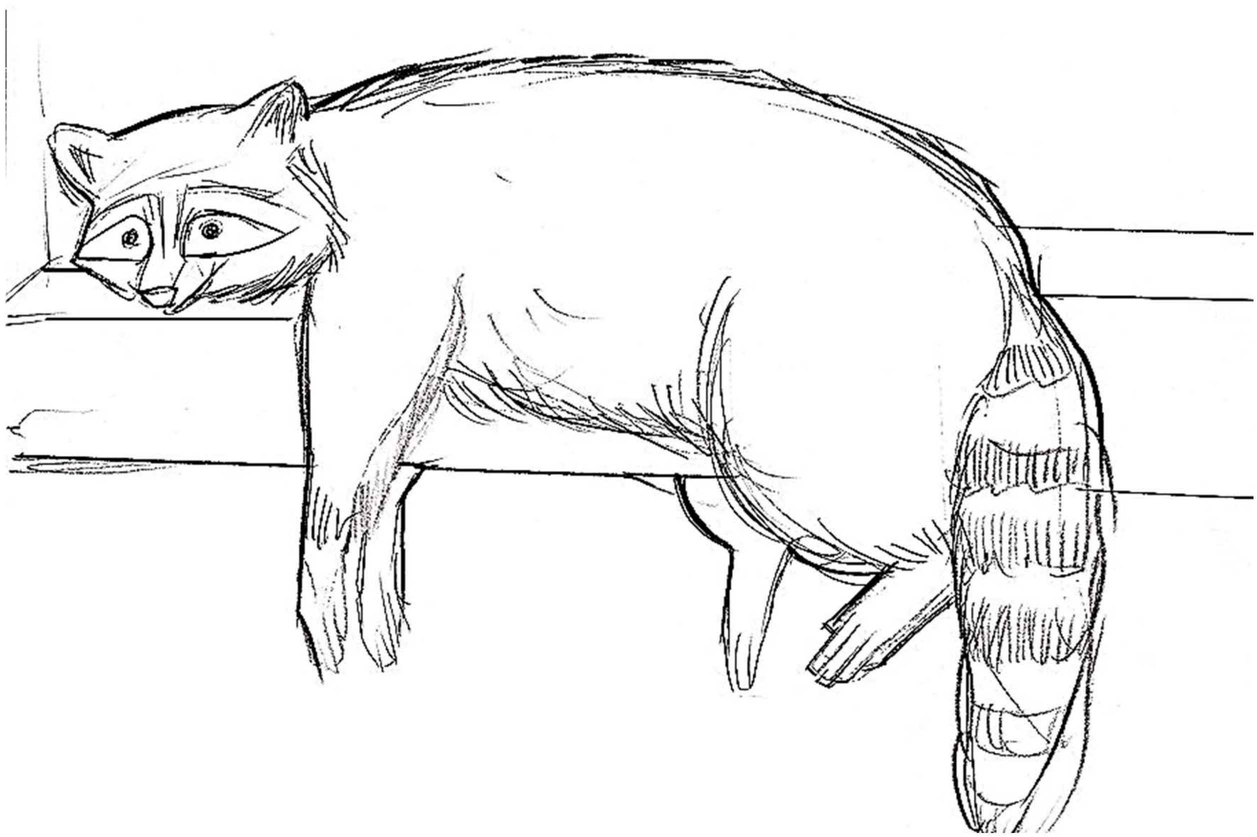


Gray Squirrel
Scientific name:



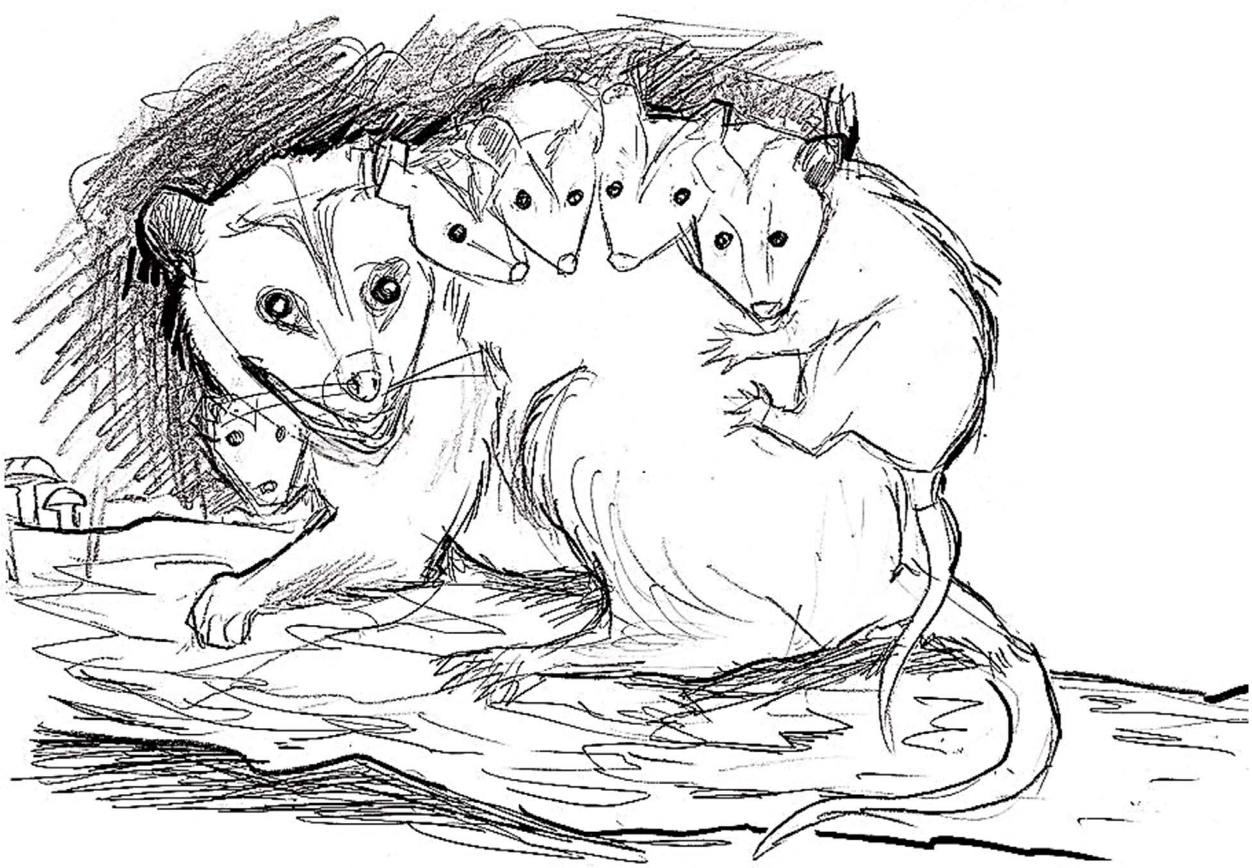
White-tailed Deer
Scientific name:

Color: Gray and Black



Raccoon
Scientific name:

Colors: Light Gray and Black



Opossum
Scientific name:

Data Sheet

Use this page to write down any animals you compared divergence times with. If you have a favorite animal include it on this page. Get together with your friends and see if you got the same divergence times and try out animals you think are related.

Animals and people also live on farms. Do you think farm animals are related? Most of the animals on farms are domesticated.

Compare a domestic goat and a chicken in Timetree.

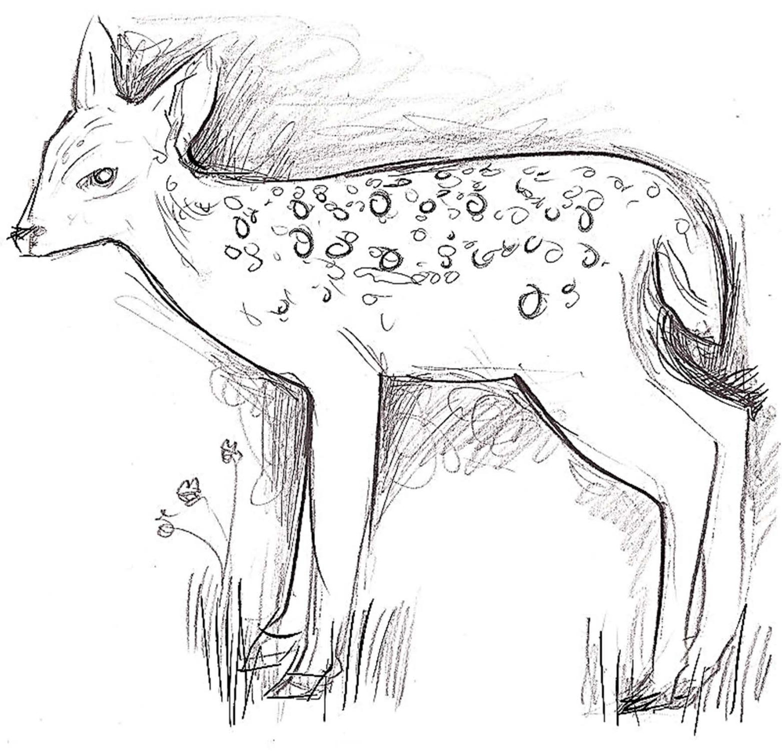
Colors: Medium Brown and White

Compare some animals that look like each other.

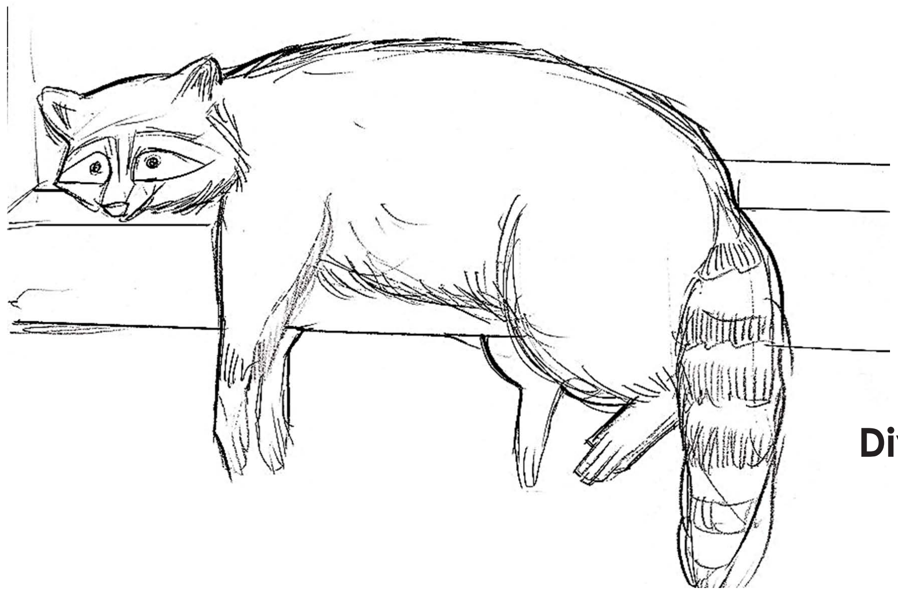
Compare Musk Deer and White-tailed Deer:

Colors: Light Brown and White

Divergence time:



Compare Raccoon and Raccoon Dog:



Divergence time:

Compare Squirrel and Flying Squirrel

Colors: Gray and White

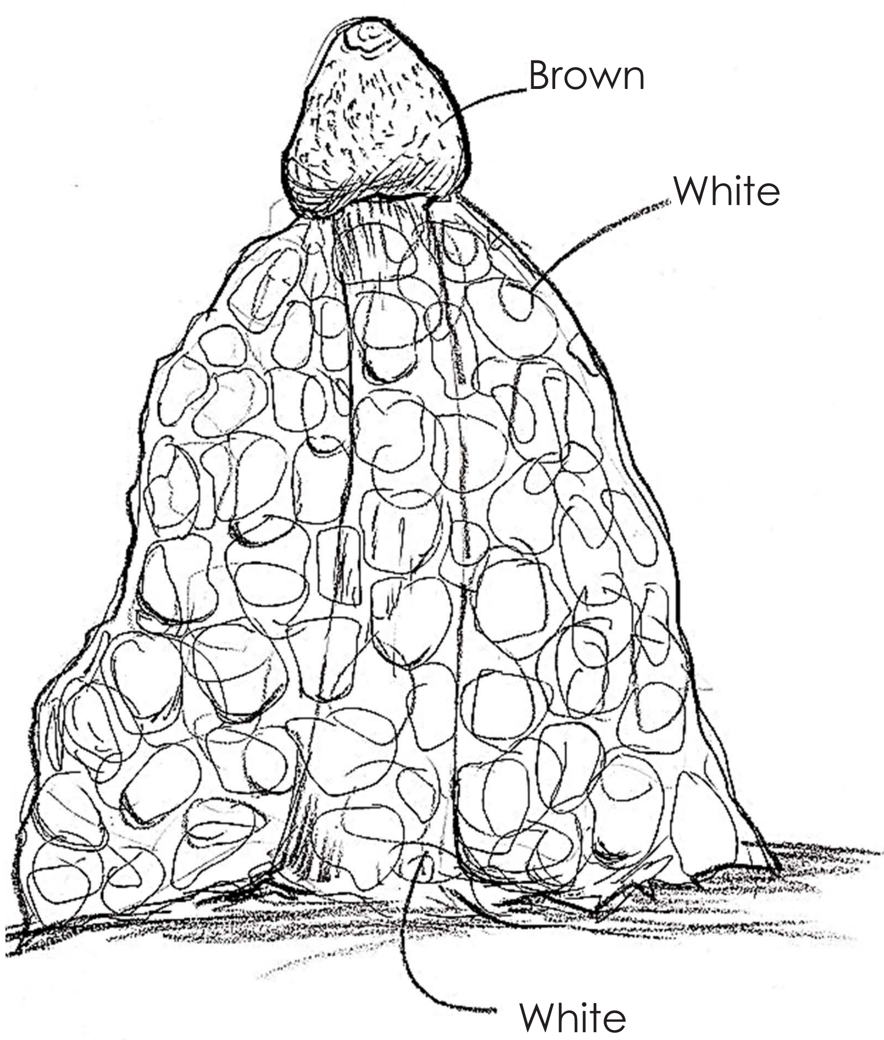
Divergence time:

Colors: Gray, Brown, and White

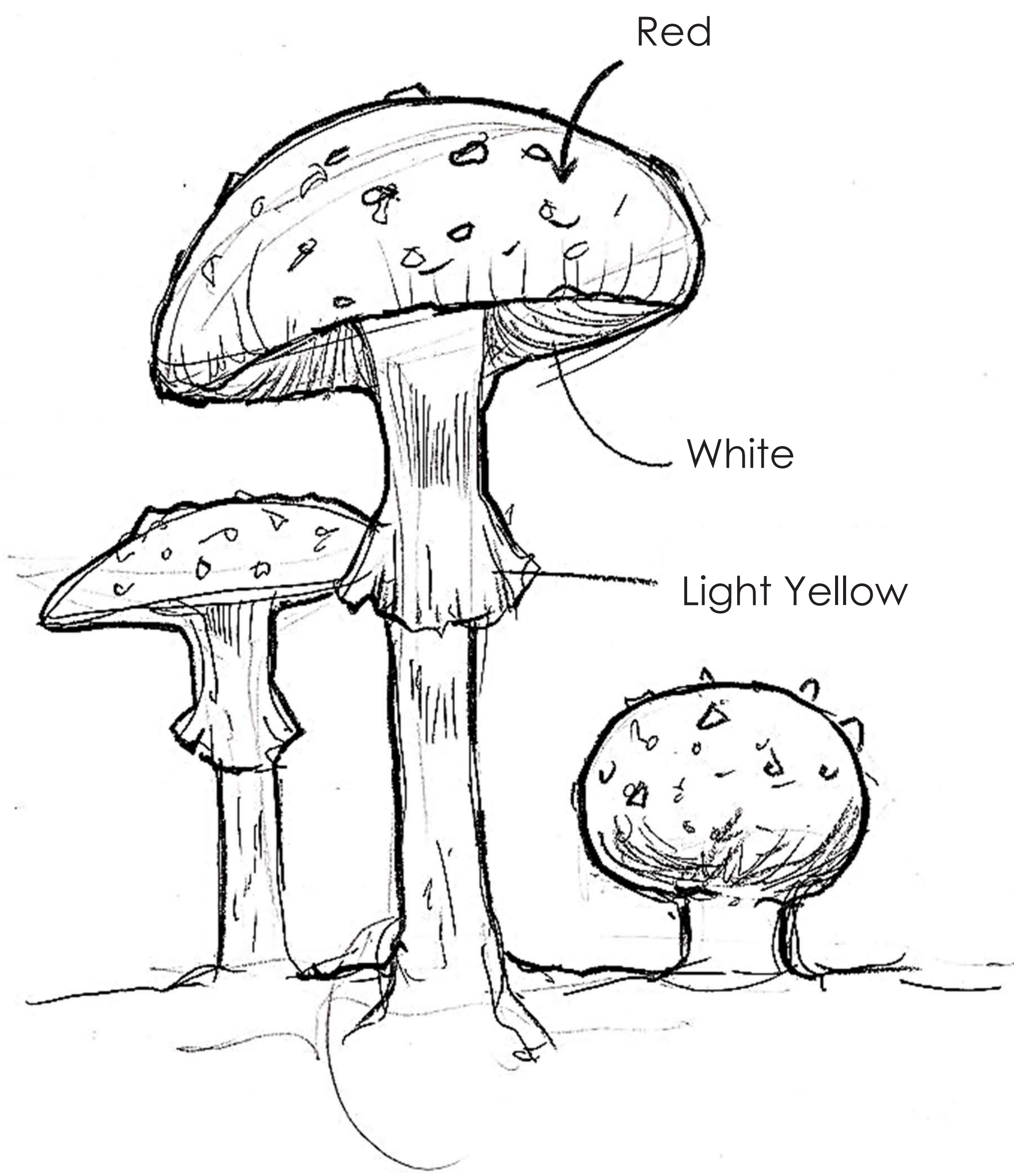
Do you ever wonder how related you are to mushrooms? Maybe you didn't know that a sponge is related to you too and that a sponge is an animal.

Sponges might not look like you but let's find out what their divergence times is compared to a person:

In the Timetree search boxes enter the following: **Stinkhorn Mushroom and Homo sapiens (that's you)**

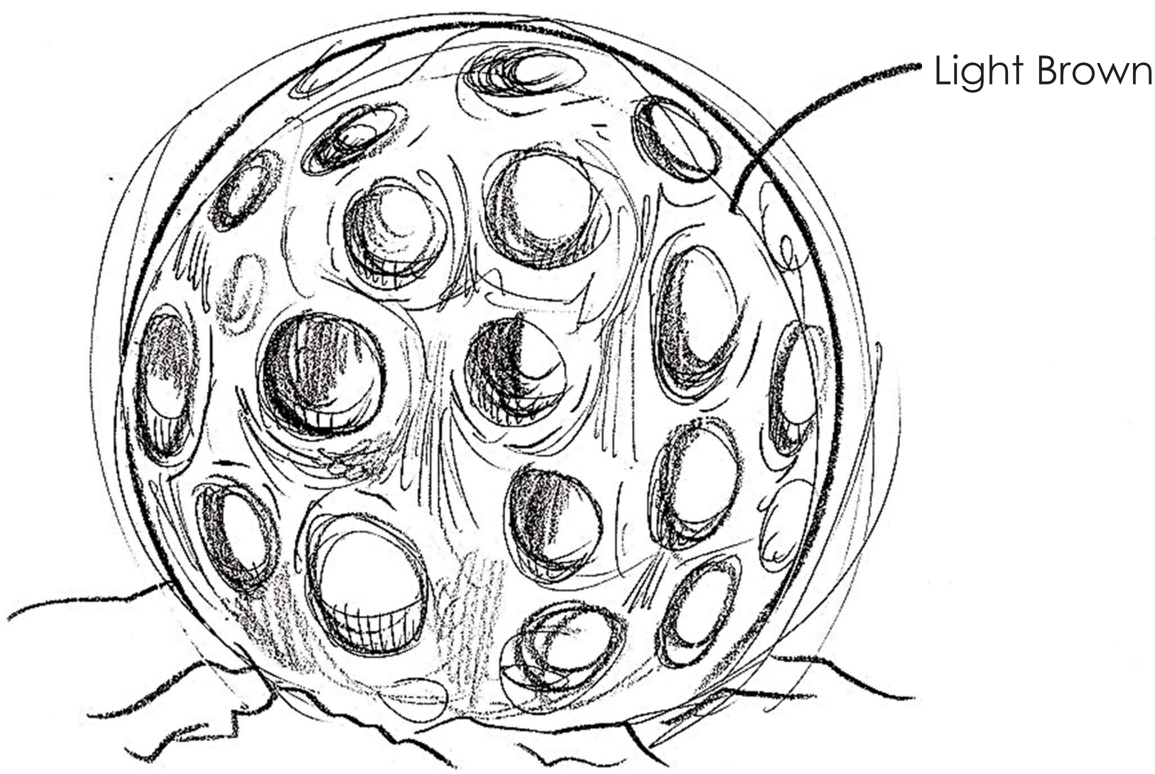


Try Fly Agaric Mushroom (*Amanita muscaria*) and Stinkhorn Mushroom (*Phallus indusiatus*)



Since a sponge is an animal and so are you, try these two sponges with Homo sapiens (remember find the scientific name if the common name doesn't work).

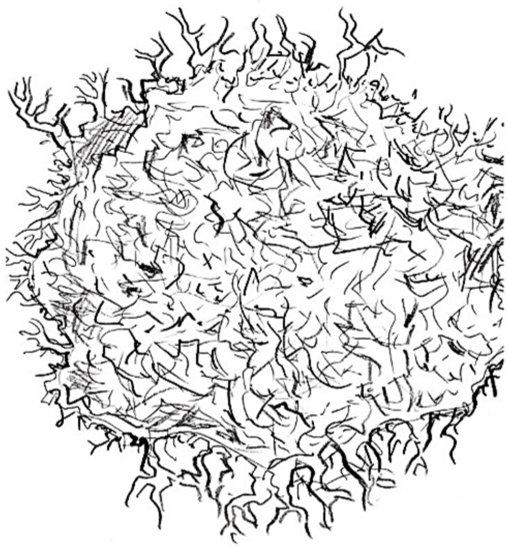
Golf Ball Sponge (*Tethya aurantium*)

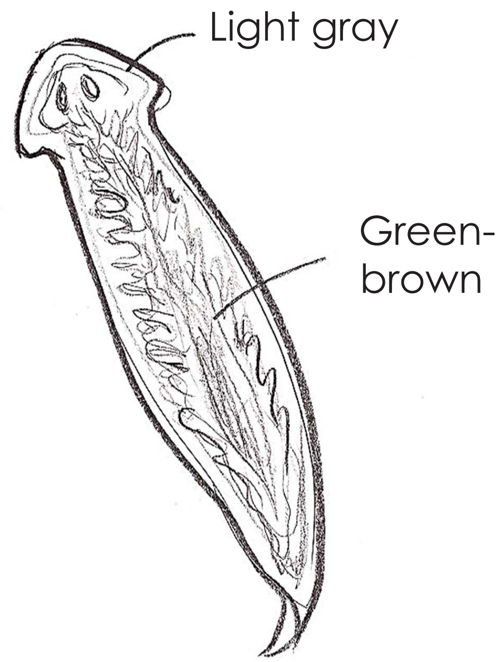


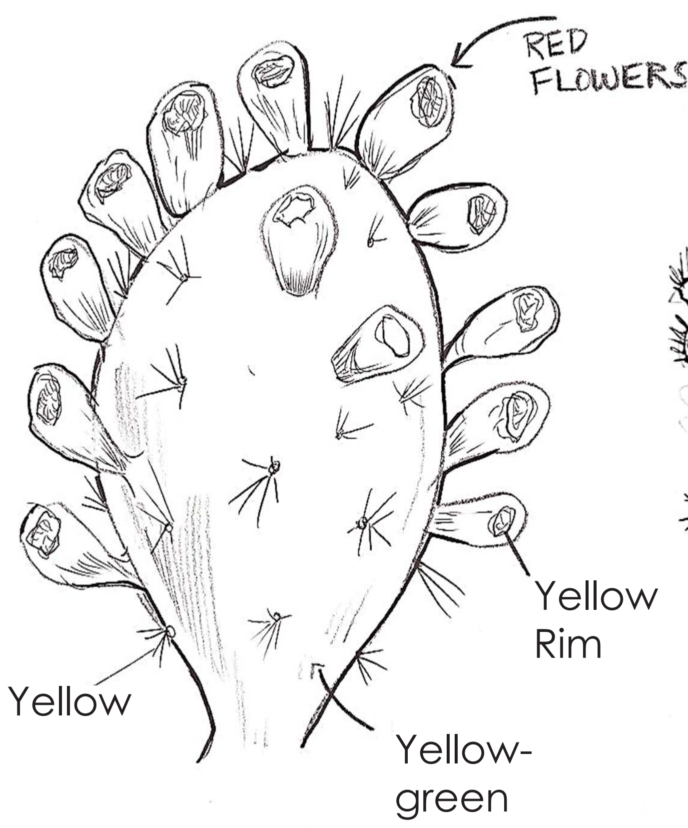
What about some other organisms? First see if you can figure out if these organisms are animals or plants. Then compare divergence times.

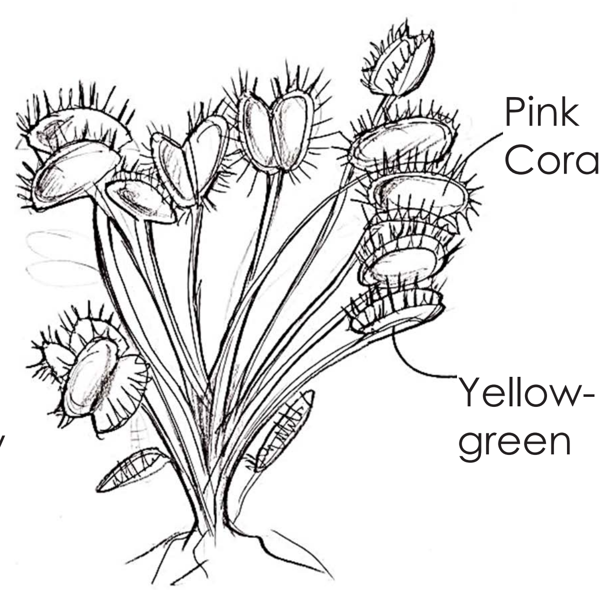
From top left to bottom right: **Lichen, Planaria, Prickly pear, Venus flytrap**

Colors: Green and Gray









Data Sheet

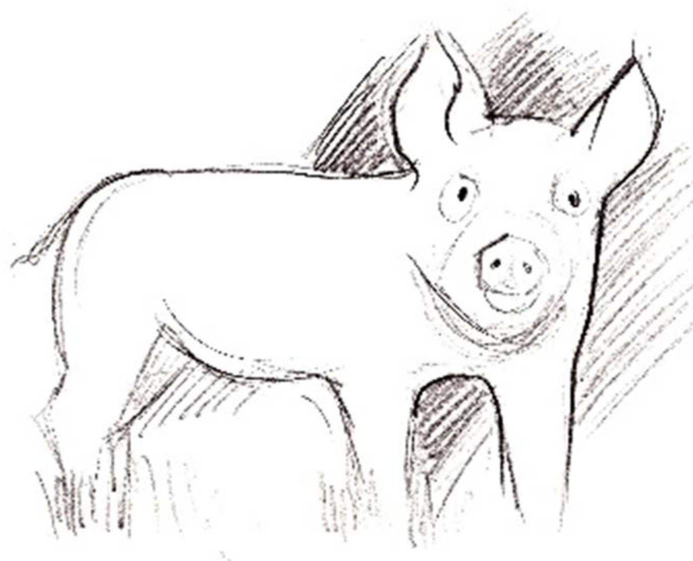
Use this page to write down any animals, plants, and fungi you compared divergence times with. If you have a favorite animal include it on this page. Get together with your friends and see if you got the same divergence times. How closely related are you to a banana?

Let’s look at some mammals with different adaptations. Some can swim, others can fly. When did they diverge?

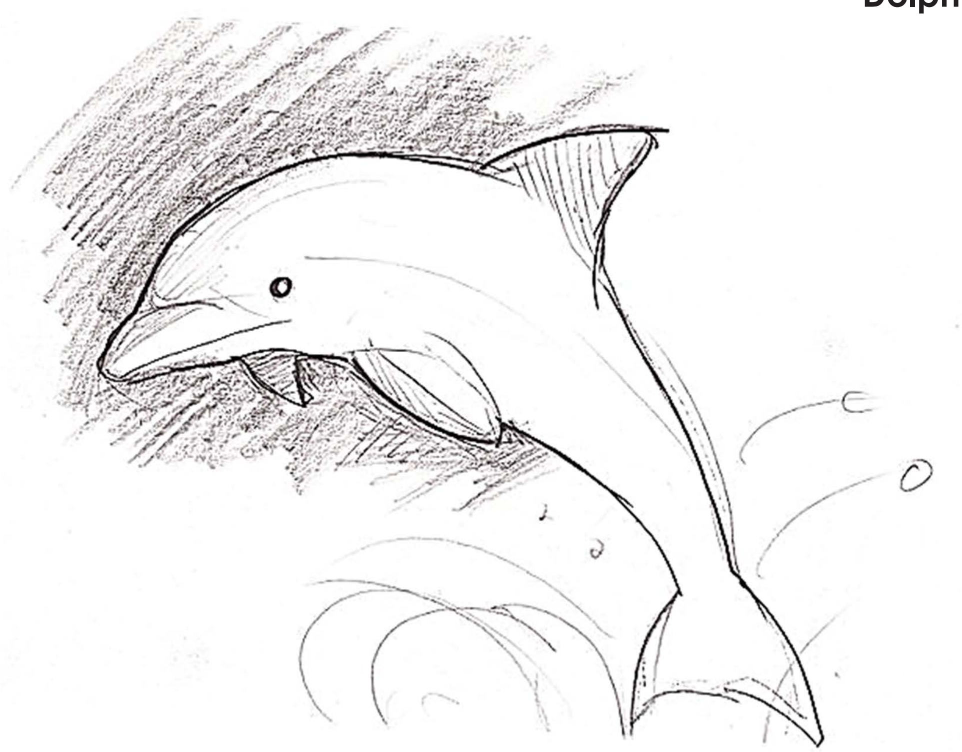
Compare and color:

Seal and Dog

Cat and Rat



Dolphin and Pig



Data Sheet

Use this page to write down any animals (or plants) you compared divergence times with. If you have a favorite animal include it on this page. Get together with your friends and see if you got the same divergence times.

Who are you most related to?

Here is a list of animals. Find out who has the longest and shortest divergence times.

Elephant Shrew and Human

Snub-nosed Monkey and Human

Gorilla and Human

Gibbon and Human

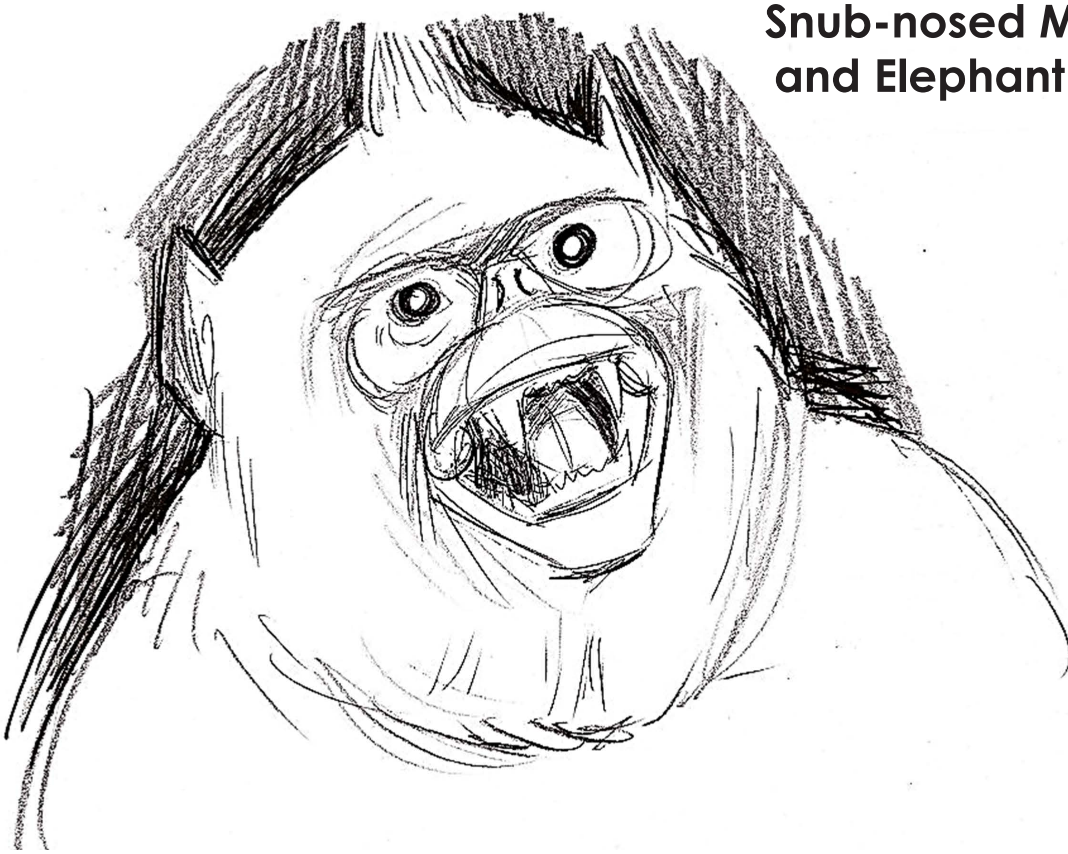
Cat and Human

Gorilla and Gibbon

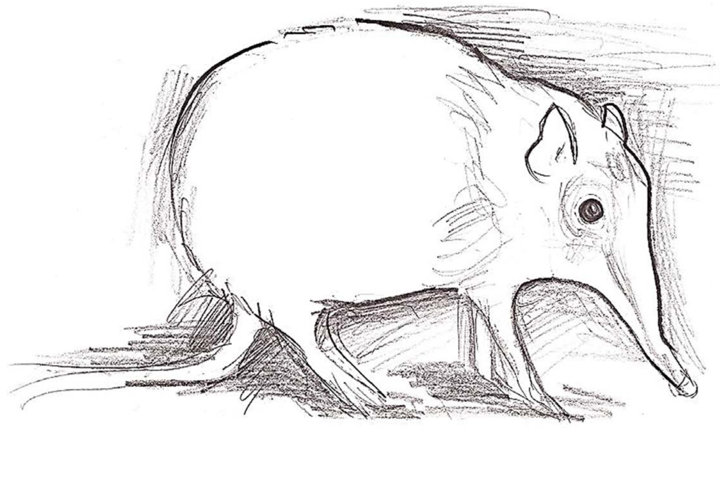
Colors: Gold and White

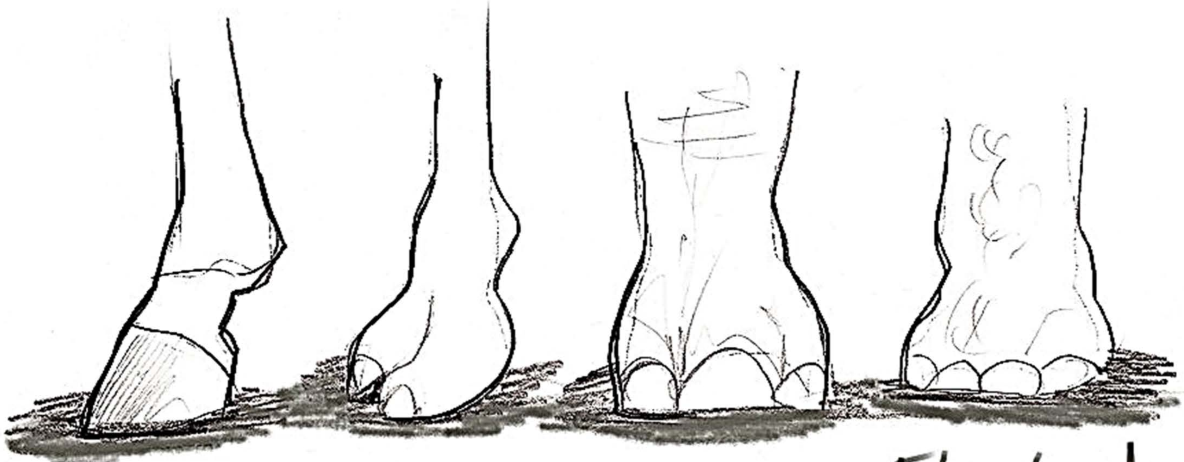
Colors: Bright Orange, Blue, and White

Snub-nosed Monkey and Elephant Shrew



Colors: Brown and Yellow





Horse (1 toe)
1. zebra
2. Donkey

Camel (2 toes)
1. COWS
2. sheep
3. GOATS
4. PIGS
5. Deer
6. LLAMA
7. ALPACA
8. Buffalo

Rhino (3 toes)
1. Tapirs

Elephant 4 toes (BACK)
1. BIG cats
2. weasels
3. skunks
4. OTTERS
5. Bears

Here we have four different types of feet and toes. Underneath the representative foot, you will see other animals which share this trait.

Go into Timetree and search divergence times between different animals.

Can the number toes mean a closer relationship?

Find out and write down your answers on the next page.

	Divergence time

1. Horse and Zebra
2. Horse and Camel
3. Horse and Rhino
4. Horse and Elephant

1. Camel and Llama
2. Camel and Donkey
3. Camel and Tapir
4. Camel and Otter

1. Rhino and Tapir
2. Rhino and Zebra
3. Rhino and Buffalo
4. Rhino and Bear

1. Elephant and Bear
2. Elephant and Pig
3. Elephant and Donkey
4. Elephant and Camel

Appendix

Climbing the Timetree of Life K-12 Activity Lesson Plan for Teachers

Introduction

Darwin's evolutionary tree is one of the most famous, metaphorical trees in science history. Trees of life have been around in many cultures and for over thousands of years. Tree metaphors are useful for visualizing the many branches of knowledge and the expansion of species on Earth. Young children can learn about evolution by organizing knowledge in categories and in timelines. Tree analogies create a sense of flow in both time and in the evolution of species through a visual metaphor. Most timelines are one-dimensional arrows of time moving forward continually. This is primarily the way prehistory and evolution are conveyed to young audiences. Introductions to dinosaurs and extinct species sets the tone for most early educational settings. The rise of life, the almost imaginary organisms of the past and enormity of time makes evolution a naturally fascinating topic for younger audiences, but a complex one. Evolution has many levels of complexity from extremely long-time frames to the multifaceted molecular changes over time. These can appear somewhat abstract, but they do elucidate evolutionary processes and are the current methodology used to construct evolutionary or phylogenetic trees. Is there a way to start discussions on evolution as a process and engage students directly with an experience that allows discovery of evolution's many moving parts? The Timetree of life database may provide such an experience. The Timetree of Life (TTOL) is a database developed by two evolutionary biologists, Blair Hedges and Sudhir Kumar who compiled published works containing species DNA sequence data to construct and visualize the comparison of two species diverging. This database consists of published works from around the world constructed into one website where researchers and students alike can search for a geological timeline between specific species that interest them. Divergence is another way of explaining when species "split" and become new species. Comparing species' times of divergence reveals relatedness between those two species and how much geological time has passed since they split. TTOL contains many fundamental concepts in evolution and engages users in an entertaining and exciting quest to compare species with each other and with themselves. In this way it creates an early sensitivity to other life forms and encourages conceptually a unity of life over geological time and a greater appreciation for all organisms, not just the well-liked, familiar animals. This can build a strong ecological and evolutionary base for students early in their experience with science. Evolutionary concepts underlie all other biological knowledge and with TTOL, younger students may consider biology from an evolutionary perspective early in life and in a fun interactive setting.

Visualizing Evolutionary Process

Children naturally enjoy working with visual information and much of their instruction and learning is from visual elements. Visual literacy develops the skill of contemplation and formation of words, concepts, and hypotheses. Visual learning offers students the opportunity to manipulate knowledge, engage with materials and ideas, and experiment outside of their own mind by observing the results of their own activities. The application of visual thinking to evolution is valuable for early learners. Geological time scales and species diverging and adapting are all processes that we cannot directly see. The broad expansive nature of both ecology and evolution that have intertwined temporal and spatial elements can be confusing for even adults. The Timetree database, in many ways, simplifies the vastness of geological time and streamlines the theory of evolution in its graphic representation of speciation. The complexity of divergence becomes a visualized experience of evaluating evolutionary relationships.

How Does TTOL work?

The Timetree database is easy to use and requires only that the user know the general name of an organism. If a genus and species is known this also works, especially when comparing two similar species. For example, if you type in "cat" and compare its divergence from "dog," "cat" will be assumed as Felis, and dog will be assumed as Canis. If, however, you wish to compare divergence times of a Leopard Cat to a Caracal Cat, you will have to use scientific names, or genus and species names. Timetree has many functions, but for K-5 students, simple species comparisons would be sufficient. As simple as it may seem there is a great deal of evolutionary teaching that can spring from comparing two species, and this gives educators much freedom in constructing interesting and powerful lesson plans and experiences with evolution for students.

Building Unified Knowledge on a Unified Planet

Some of the concepts that can grow from the Timetree experience include, evolutionary thinking such as speciation, divergence, DNA sequences, genomes, variation, mutation, geological times scales, classification, phylogenetics, divergence times, molecular clocks, fossil evidences, ecosystems, and biological diversity. Timetree itself is a synthesis of published evolutionary trees, which are scaled to time and therefore not just evolutionary trees, but "timetrees." Instructing young children about these broad universal concepts may allow them to form ideas about living systems in a planetary way and in a less narrowly focused perspective because Timetree lets you compare your evolutionary linage with that of any other organism, provided the published data is available. It is the inclusion of oneself in the evolutionary stage that broadens the mind. In the age of the “6th” extinction, this critical analysis of our relationship with all other life is essential to address the underpinnings of future climate change, disease development, habitat loss, collapse of ecosystems, extinctions, and new niches. This is a powerful way to shape a young mind for a future that should be inspired by nature. Exposing children early to evolutionary concepts develops an appreciation of biological diversity, intact ecosystems, health, and their own personal human journey on this planet. Tree-of-life information provides an easy framework for students to organize their knowledge about living, interactive networks.

Evolutionary-Interdisciplinary Discovery

For a teacher, Timetree allows a variety of interdisciplinary and evolutionarily focused lesson plans to be created. As an example, we have provided an interdisciplinary, STEAM-based lesson plan to accompany this article. The scientific basis of Timetree may also serve as a unique platform for understanding DNA and the sequence data required for the calculations used to make timetrees. In K-5 classrooms, students learn about the cell. The eukaryotic cell contains a nucleus and from this point, the idea of DNA, its 4 bases and the genetic code can start a discussion on DNA sequences and their variations in different species. It is the variations of nucleotides and the proteins they make that are the basis of recreating the life histories of organisms. Moving from the cell to DNA connects the cell to evolutionary concepts and the methodology behind the Timetree website. Students also may be introduced to the idea of using math to understand rate of change in evolution and “molecular clocks.” Elementary school science teachers can give their students an opportunity to become “scientists” as they explore the interesting relationships and comparisons of various organisms and their divergence times. Scientists require accurate divergence times to calculate rates of change in genes, proteins, and organisms so they can better understand the evolution of complex biological systems, ecosystems, and the evolving web of life. Students can duplicate much of what a scientist might do with Timetree. Educators can easily learn how to use Timetree themselves and come to appreciate the unified computational knowledgebase that results in tree building, expanding their capacity to bridge ecology to evolution and to the cell. Educators may also assist students in developing discovery strategies that build unified knowledge.

For our lesson plan with Timetree we have decided to focus on exploring the biodiverse origins of an average American breakfast. This is something that students can begin at home and develop further in the classroom with the assistance of their teacher.

Probing Timelines with DNA and Algorithms?

TimeTree is a unified computational knowledge base that synthesizes published data with a unique tree-climbing algorithm. Users may obtain and export timetrees of any group, or a custom list of species. They may also obtain a timeline showing evolutionary branches from the perspective of any selected species, going back in time to the origin of life. Events in geological and astronomical history such as Earth impacts, oxygen levels, and solar luminosity, are synchronized in the same timescale with biological timetrees and timelines, facilitating cross-disciplinary discovery (REF).

Just mentioning to students that they will be "sleuthing" an evolutionary timeline of life on Earth, is tantalizing to a young mind. This may inspire students to find the timeline of their hamster, dog, goldfish, or favorite animal. A class walk through the woods can be turned into a Nature Journal and then into a Timetree investigation of all the organisms noted and drawn in their journals. They may even compare *T. Rex* with their pet iguana. The graphics are colorful, and the data sheets can be printed out.

STEAM Experiences with Evolution

Timetree encourages a strong degree of interaction with the timelines. This can be enhanced further for younger students by having them draw the species or organisms they wish to compare in the database. To encourage students to spend more time in nature and develop drawing skills, we suggest an outdoor nature discovery experience where students explore the biology of their own surroundings. Of course, trips to zoos, aquariums, and farms can also be substituted for parks, backyards, and school grounds. Something as simple as having students draw plants, insects, and animals like squirrels, and then compare the Timetree database creates an evolutionary, art-based discovery process. In another possible lesson plan, we have students again, focusing on the familiar, and what is around them, drawing it, and then uncovering its past through TTOL. Drawing allows students to form a visual framework prior to engaging in abstract experiences such as geological time and speciation. It also provides them with accomplishment and perspective. Both lesson plans have been briefly outlined in tables 1 and 2.

"Starting Your Day with Evolution and a Timetree Investigation: It's What's for Breakfast."

When you sit down and start your day with food, do you ever wonder where it came from? Do you ever pay much attention to what you're eating and think about its origins? For an easy entry into the world of Timetree, students can explore the origins of their own breakfast. Most of us rarely consider where what we eat came from, the ecological, social, and energetic cost to "produce" it, and its relatedness to us. Exploring food webs and food chains is a common assignment for students in science class but rarely includes the student as part of that chain or web. If we present students with a common list of breakfast-like foods, students and teachers can identify what organism they are made up of, make lists, and find divergence times of those organisms in Timetree. This is a fun, easy lesson to engage students, however, it also has the potential to delve into more complex subjects such as deforestation, energy pyramids, and population growth. For example, bacon is a popular food. Students can easily go to the Timetree database and find the divergence times between modern farm pigs and themselves. They also find the divergence times of wild boars, the ancestors of modern pigs. The topic can go further and branch off into a variety of other topics in ecology and evolution. We can also introduce food items that are less obvious, like cooking oil. One popular cooking oil is palm oil. Palm oil comes from West African *Elaeis guineensis,* from the fruit of palm trees. Here students are introduced to the least inclusive classification system of genus and species, and the idea of naming and organizing biological knowledge. Palm oil also brings in the concept of deforestation, as the majority of the palm oil sold in the grocery store is now produced in Borneo. The very charismatic and popular

Orangutan that children often see in zoos is losing its habitat to the palm oil industry, which is part of their morning breakfast. Many popular products lead to deforestation as an estimated 50% of the products we use come from palm oil. There are approximately 80,000 Orangutans left in the world and this great ape, one of our closest relatives, is facing extinction. Extinction is another important evolutionary concept that can branch off from this Timetree exercise. With extinction, students can conversely be introduced to the concept of speciation. When students compare the divergence times of a human (homo sapiens) to an Orangutan (*Pongo pygmaeus* from Borneo and *P. abelii* from Sumatra) and learn that there are surprisingly only two species of orangutan and only one species of human. At one time on planet earth there were several species of humans, another topic to explore with a question like: which organisms are also one species? Other interesting facts from Timetree demonstrate that Orangutans and humans split five million years ago and share a common linage. Any species and its divergence time can be followed with discussions on taxonomy, morphology, and ecology, all topics that younger students can "step back into" with hands-on arts and crafts activities like habitat maps, learning to draw organisms, introducing morphological characters and how they change over time, and looking at actual sequences and genomes of organisms.

Lists of "Breakfast Foods"

Bacon(pig), eggs(chicken), vanilla yogurt(vanilla bean, lactobacillus, cows), cantaloupe, honeydew, strawberries, bananas, chocolate, rye bread, wheat bread, maple syrup, kippers, milk, orange juice, grapefruits, peanut butter, mushroom omelets with peppers, onions, and spinach, tomatoes, turkey sausage, honey, cranberry juice, potatoes, soy milk, oatmeal, sugar

Educators can focus on words like splitting, branching, and divergence by using the tree metaphor.

Let's follow the thread of Orangutan. If we follow our food to species that inhabit where that food source is located, we can then weave the ecological-evolutionary thread from Timetree into a discussion on taxonomy, morphology, life stratagies, predator-prey relations, symbiosis, niche, and extinction. For example, students will find that the Orangutan is mostly herbivious. It eats fruits when ripened and available, but when in short supply it consumes bark, flowers, insects, and even the pith. In turn, Orangutans are preyed on by mid-size and large cats such the Clouded Leopard and tigers. It is also preyed upon by crocodiles, dogs, and its most destructive predator– man. We can go to Timetree to explore the relationships between the food the Orangutan eats, such as figs, and find divergence times. We can also explore the divergence times of predators like the Clouded Leopard and the Orangutan.

In habitat loss, species are dramatically affected by the destruction of niches. Many species will go extinct or shift their location and eating habits in an attempt to adapt to the rapid changes. We ask students what would happen if the palm oil grown causes a drastic reduction in habitat? What species in the ecosystem would be most affected? What happens if the Orangutan becomes extinct? What is extinction? Does everything go extinct? What is the difference between mass extinction and background extinction? What species would be most affected? We can then introduce the concept of the niche. What are niches? How do they come into being? How are niches filled? What would a bird or a bat need that would constitute their niche? This would bring our discussion full circle back to the exercise of divergence and speciation. While these are extraordinarily complex issues, they are part of normal evolution and are abundantly present in the world humans have created.

Conclusion

Exploring divergence times through the Timetree of Life and combining it with hands-on activities of creating food webs and food chains allows an easy introduction to some of the most important concepts in evolution. These concepts provide a growing intellectual and creative framework for students to contemplate our living world and their place in it. Educators can construct and develop lessons encouraging students' own unique discovery processes, centered around hands-on activities and the Timetree database, inspiring a broad, interdisciplinary context for ecological and evolutionarily modeled thinking.