DEEP TIME SCALE: AN ACTIVITY FOR ALL AGES

Grasping the length of millions or billions of years can be difficult for people of any age. This exercise helps bring the age of the universe into perspective with key milestones between its beginning and present time. Different scales can be chosen depending on how much time and space you have to work with.

For the classroom-sized activity, one million years will equal one millimeter. If space is available outdoors or in a gymnasium and time sufficient to walk a greater distance, the activity can be scaled up so that one millimeter can represent 100,000 or 10,000 years. With one millimeter representing a million years, the age of the solar system will equal 5 meters. Using one of the larger scale options will result in a 50- or 500-meter distance, a little more than the circumference of a quarter-mile running track.

This activity can be done together as a class or by groups of 2-4 students. For the classroom-sized activity, each group will need a roll of register paper, masking or painter's tape, and a ruler or measuring tape. For the larger scale activities, a tape measure is recommended and marking the distances is optional as they can just be walked. If no measuring tape is available, one lunging stride can be counted as on meter, or 1,000 millimeters. The following is a list of suggested milestones with how many years ago the events occurred.

Event	Age in years	1mm : 1,000,000 years	1mm : 100,000 years	1mm : 10,000 years
End of the Ice Age	10,000	0.01mm	0.1mm	1mm
Our species (*H. sapiens*) appears	200,000	0.2mm	2mm	2cm
Upright-walking primates appear	7,000,000	7mm	7cm	70cm
End Cretaceous extinction event	65,500,000	6.55cm	65.5cm	6.55m
Earliest mosasaurs appear	92,000,000	9.2cm	92cm	9.2m
Earliest chelonioids (sea turtles)	110,000,000	11cm	1.1m	11m
Earliest two-winged birds appear	131,000,000	13.1cm	1.31m	13.1m
Earliest four-winged birds appear	167,000,000	16.7cm	1.67m	16.7m
Earliest plesiosaurs appear	204,000,000	20.4cm	2.04m	20.4m
Earliest pterosaurs appear	228,000,000	22.8cm	2.28m	22.8m
Earliest dinosaurs appear	243,000,000	24.3cm	2.43m	24.3m
Sharks and bony fish appear	420,000,000	42cm	4.2m	42m
Earliest vertebrates appear	520,000,000	52cm	5.2m	52m
Ealiest eukaryotes appear	2,100,000,000	2.1m	21m	210m
Earliest life (fossil bacteria)	4.200,000,000	4.2m	42m	420m
Earth formed	4,600,000,000	4.6m	46m	460m
Solar system formed	5,000,000,000	5m	50m	500m
Universe formed	13,800,000,000	13.8m	138m	1.38km

Going the full distance for the age of the universe is entirely optional. You may find it better to just point out that the universe is 2.75 times older than our solar system.

Above: Clidastes *is a small, relatively primitive mosasaur. Mosasaurs were a short-lived group of reptiles. They first appear in the fossil record 92 million years ago and went extinct at the end of the Cretaceous a mere 26.5 million years later along with all of the world's remaining species of pterosaurs, plesiosaurs and for the most part, dinosaurs.*

Survivors of the Mass Extinction: An Activity for Advanced Students

Every species that is alive today has an ancestry that can be traced back to the earliest life on Earth. For this exercise, we will trace back the lineage of a selected species at least as far back as the Cretaceous, 65.5 million years ago or more. The activies involved can be done together as a class, individually or as pairs, but will require a web browser with access to Wikipedia.

Select a species of vertebrate which is extant, meaning the species is living today. Search for that species on Wikipedia and trace back its evolutionary history by researching the scientific classification links at the top of the article for that species. Working your way up the list of classification links progresses toward more general tiers of biological classification. Each tier up the list should include more groups of vertebrates and will often push back further in time the occurrence of animals representing that group as shown by the geologic time scale that appears above the scientific classification links.

Create a chain of ancestry by writing or typing the selected species and the scientific name for each tier on the way back to the Cretaceous. Once the tier that reaches to the Cretaceous has been found, note the scientific name of that tier as well as what level of tier it is (i.e. subclass, order, family or if it is an unnamed tier, usually just called a "clade" when no name exists for the tier). Thoroughly study the article for that clade and list some of the other species that are part of that clade, but that lived during the Cretaceous; as close to the Late Cretaceous as you can find. The species you find here will be the closest known relatives of the species you selected in the times of the Western Interior Seaway.

Left: *As an example, selecting the Komodo dragon as the modern species to trace back to the Cretaceous would lead to varanoid reptiles, including mosasaurs, like this* Tylosaurus*. The species name for the Komodo dragon is* Varanus komodoensis*, a member of the "varanoidea" the "superfamily" which includes mosasaurs.*

Classroom Museum: An Activity for Younger Students

Discovering and sharing what you find to be most interesting about your experience is a fun way to include parents or other classes who may not have been able to visit the exhibit. Working together to tell the story of these ancient oceans in your own classroom exhibition reinforces what everyone learned and gives them a chance to express themselves creatively.

Work together to assign or select creatures that will result in a diverse exhibit. Students can create their creature from scratch by drawing the skeleton or life model and carefully cutting it out with scissors, or by cutting out a printed digital image. More advanced young students can work together in the design process to decide on a size scale and try to make the relative sizes in their exhibit consistent with the relative sizes of the fossils. Previous pages in the guidebook provide measurements that can be used to create your exhibit components to scale. Working together, plan the exhibit layout on graph paper to make sure all of your specimens will fit in the exhibit. Students can design signs to display with the specimens or verbal presentations that explain the name of and details about their creature.

The exhibit can be created two-dimensionally on a bulletin board or three-dimensionally suspending each model on strings. If creating a bulletin board background, we recommend a cross section perspective that has space in the sky for birds and pterosaurs and a lot of room underwater for everything else. If suspending each model on strings, remember to attach models at two different points if you want your models to hang without spinning.

Stratigraphy Pie: An Activity for Younger Students

The principles of geology are the foundations of earth science. This activity highlights a few of them: superposition, original horizontality, and faunal succession. Superposition states that younger sediments are deposited on top of older strata. This stands to reason because without an older surface to deposit onto, where would sediments land? Original horizontality states that sediments are deposited in horizontal layers. This happens because gravity pulls fluids and sediments toward the center of the planet causing them to flatten and level out. Faunal succession states that fossils are found in a specific, reliable order with various species succeeding one another vertically through stratigraphic layers, and this pattern can be correlated from one place to another.

Clear plastic cups are a crucial element for this exercise to allow viewing the layers in cross section. The ingredients you use in your stratigraphy pies can vary, but here are some suggestions:

ALWAYS BE MINDFUL OF ALLERGY RISKS. Avoiding peanuts, tree nuts, dairy, gluten and/or preservatives may be necessary to avoid the allergic sensitivities or dietary restrictions of all participants.

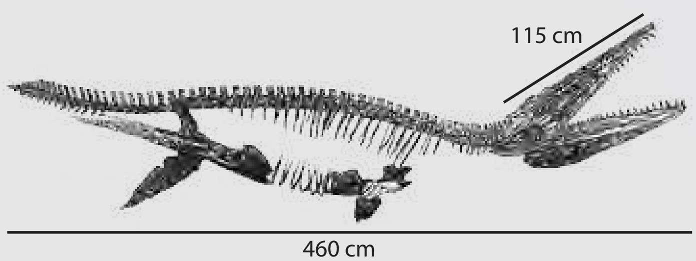
Puddings; at least two different colors. You can also use food coloring to make unique colors.
Gummies; various animal shapes including bears, sharks, frogs, fish, worms, etc.
Chocolate chips/sprinkles; bring a little humor to your stratification with a discussion about coprolites...
Crushed graham cracker and/or "Oreos"; purchase premade or crush your own in bags.
Powdered sugar or "Pixie Stix"; great for thin layers of fine-grained sediments like "volcanic ash"
Caramel or chocolate sauce; A thin layer should always settle flat and horizontal; also a nice tar-pit topping.

Sea Monster Engineering: An Activity for Intermediate Students

Engineers use drawings to represent precisely how something is shaped and sized. Each important element of their drawings are marked by measurements that detail the placement of these features. For this activity, students will need the lengths for and images of various creatures of the Savage Ancient Seas, rulers, and graph paper is also helpful.

Measure the image that will be the basis for the student(s) reconstruction. Divide the given length of the creature by the measured length of the image to find the scale factor between the image to the real fossil. If your organism is 10 meters (1,000cm) long and the image is 10 centimeters long, the scale factor is 100:1, meaning the animal is 100 times longer than the image. Next decide how large the drawing of the creature is going to be. To continue the example, you may choose to make a drawing of the creature 20cm long. This would be twice the size of the source image or 1/50 the size of the original fossil.

To help accurately draw each element of the creature to correct proportions, measure the image as you go. Multiply the measurements taken from the image by the calculated scale factor. Draw guide lines or points to show where each element of the creature will land on the page after scaling. For example, if your animal has fins or flippers, measure the length and width of each as you prepare to draw them. Multiply those measurements by the scale factor and lightly mark on the drawing where the base, tip and width of each element should be relative to the rest of the drawing. Draw each fin or flipper so that it fits exactly within the points and guidelines you drew. This will help make your drawings precise in proportions. You can also label the guide lines used in the drawing or draw new ones with measurements included.



Left: *An example of an illustration with dimensions added for the length of the full skeleton and the skull length.*

Mysterious Endings: An Activity for Advanced Students

Illustrate the extinction at the end of the Cretaceous. Draw this as one large landscape image or as a series of smaller images forming a sequence. Your artwork can depict a serious ending, like an asteroid impact or massive volcanic eruptions. It might also depict a silly ending with alien invaders or malicious unicorns as the culprits. Everyone should present their work, but not explain it at first. Let the viewers interpret the work and try to explain what they see. The creator can either affirm when someone guesses correctly or leave the intent of their image a mystery.

Fishy Flip-Book: An Activity for Younger Students

Have everyone in the group draw two to five simple fish outlines exactly 3 inches long and one inch tall on the corner of a page with the fish swimming toward the corner. It is important that everyone's fish is nearly the same size and is generally facing the page corner, but the shape and orientation of the fish can vary. Collect everyone's fish drawings and stack them up with all of the fish in the same corner of the stack. Hold the pages together tightly and have everyone watch as you flip through the corner. The slight variations in everyone's fish might make the resulting animation feature a fish that looks like it is swimming, floundering around on the ground or even changing color if some participants used different colors. Try shuffling the pages up to see if different patterns emerge when flipping through them.

Cretaceous Crossword: An Activity for Intermediate Students

Make a crossword puzzle featuring answers from the Cretaceous. You can do this by hand (graph paper helps) or using an online crossword puzzle generator to speed things up. Choose ten to twenty terms relevant to the Late Cretaceous. This includes names of creatures in the exhibit (i.e. *Tylosaurus)*, the larger groups these creatures belong to (i.e. mosasaurs), or other terms that might be pertinent (i.e. extinct, marine, predator, you get the idea!). Be sure that your clues are accurate and only describe an answer that fits the space in your puzzle.

Bones and Eggshells: An Activity for Younger Students

For a bone to become a fossil and survive for millions of years, a few conditions must be met. The bone needs to be buried before it is weathered away. It must remain buried until just before being discovered, also to avoid weathering away. While buried, the conditions in the ground must not become acidic, because this will dissolve bones. Both bones and eggshells are composed of calcium carbonate. Acids dissolve calcium carbonate. Even relatively weak acids like vinegar will slowly perform this dissolution.

For this experiment, a jar with a lid will be needed for each item to be submerged. Clean bones of any sort, such as chicken bones, pork ribs or the hard part of a T-bone steak, will work for this experiment but you may choose to just use an egg. Place your specimen to be dissolved in the jar and submerge it in white vinegar, capping the jar when everything is inside. Overnight, the acidic vinegar will slowly dissolve away the eggshell, softening the shell and forming small bubbles of gas resulting from the chemical reaction. Bones will take a few days to soften noticably, but should also form bubbles after a day.

After about one week, the egg's shell should almost completely dissolve, leaving a "naked" egg through which you can see the yellow yolk and clear albumen (the part that turns white when cooked). After a week the bones will be softened enough that you can remove them from the jar and bend them with your fingers.

Savage Ancient Seas

Getting the Most Out of Your Visit to the Exhibit

This compilation of national science standards that correlate with the exhibit and classroom activities is provided to help take advantage of the learning opportunities inherent therein. These are not necessarily the only science standards that can be addressed, but are examples that will help educators be mindful of ways to harness the power of this unique shared experience throughout the year.

National Science Standards: K-4

K.Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment

Use observations to describe patterns of what plants and animals (including humans) need to survive
Use a model to represent the relationship between the needs of different plants or animals (including humans)and the places they live.

1.Structure, Function, and Information Processing

Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs.
Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents.

2.Interdependent Relationships in Ecosystems

Make observations of plants and animals to compare the diversity of life in different habitats.

2.Earth's Systems: Processes that Shape the Earth

Use information from several sources to provide evidence that Earth events can occur quickly or slowly.

3.Interdependent Relationships in Ecosystems

Construct an argument that some animals form groups that help members survive.
Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago.
Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

3.Inheritance and Variation of Traits: Life Cycles and Traits

Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.
Use evidence to support the explanation that traits can be influenced by the environment.
Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.

4.Structure, Function, and Information Processing

Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.
Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.

4.Earth's Systems: Processes that Shape the Earth

Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time.

5.Matter and Energy in Organisms and Ecosystems

Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain body warmth) was once energy from the sun.
Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

National Science Standards: Middle School

MS.Matter and Energy in Organisms and Ecosystems

Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

MS.Interdependent Relationships in Ecosystems

Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

MS.Growth, Development, and Reproduction of Organisms

Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms

MS.Natural Selection and Adaptations

Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.

Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.

Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

MS.History of Earth

Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.

Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

MS.Human Impacts

Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

National Science Standards: High School

HS.Interdependent Relationships in Ecosystems

Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

HS.Natural Selection and Evolution

Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

HS.History of Earth

Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.

Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.

HS.Earth's Systems

Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.

Root Words from Greek and Latin

Scientists use root words from the Greek and Latin languages when constructing terms to describe things like features of anatomy or new species of organisms. Greek and Latin are both ancient languages that have been historically studied by acadmeics in most of the world's various cultures. This makes Greek and Latin ideal for communicating ideas between scientists who do not speak the same languages. For Greek and Latin roots in addition to those found in these lists, see the names and pronunciations of the creatures in the exhibition in earlier pages of this Educator's Guide.

Common Latin Roots

Latin Root	Definition	Examples
ambi	both	ambiguous, ambidextrous
aqua	water	aquarium, aquamarine
aud	to hear	audience, audition
bene	good	benefactor, benevolent
circum	around	circumference, circumstance
contra	against	contradict, encounter
fac	to do; to make	factory, manufacture
form	shape	conform, reform
fort	strength	fortitude, fortress
fract	to break	fracture, fraction
ject	throw	projection, rejection
mal	bad	malevolent, malefactor
mater/matri	mother	material, maternity
pater/patri	father	patriarchy, patriot
mit	to send	transmit, admit
mort	death	mortal, mortician
multi	many	multimedia, multiple
pater	father	paternal, paternity
sect/sec	to cut	bisect, section
sent	to feel; to send	consent, resent
spect	to look	inspection, spectator
struct	to build	destruction, restructure
vid/vis	to see	video, televise
voc	voice; to call	vocalize, advocate
nulli	zero	nullify, annull
uni	one	universe, unify
bi	two	bicycle, binary
tri	three	triangle, triple
quad	four	quadrant, quadrilateral
quin	five	quintuple, quintet
dec	ten	decade, decathalon
cent	one hundred	century, percent
kilo	one thousand	kilogram, kilometer

Common Greek Roots

Greek Root	Definition	Examples
anthropo	man; human; humanity	anthropologist, philanthropy
saur	reptilian	dinosaur, saurian
tylo	knob	*Tylosaurus*, tylosis
xipho	sword	Xiphactinus, xiphoid
auto	self	autobiography, automobile
bio	life	biology, biography
chron	time	chronological, chronic
dyna	power	dynamic, dynamite
hetero	different	heteronym, heterogeneous
homo	same	homonym, homogenous
hydra/hydro	water	hydration, dehydrate
hypo	below; beneath	hypothermia, hypothetical
hyper	above; over	hyperactive, hyperbole
logy	study of	biology, paleontology
meter/metr	measure	thermometer, perimeter
micro	small	microbe, microscope
morph	form; shape	morphology, morphing
phil	love	philanthropist, philosophy
phobia	fear	claustrophobia, phobic
phon	sound	phone, symphony
photo/phos	light	photograph, phosphorous
pseudo	false	pseudonym, pseudoscience
techno	art; science; skill	technique, technological
tele	far off	television, telephone
therm	heat	thermal, thermometer
mono	one	monacle, monotone
di	two	digress, diplomat
tri (same as Latin)	three	triathalon, tripod
tetra	four	Tetris, tetrapod
penta	five	pentagon, pentacle
hex	six	hexacomb, hexagon
octo	eight	octopus, octagon
dec (same as Latin)	ten	decible

Resources on the Internet

Additional Classroom Activities:

National Earth Science Week
https://www.earthsciweek.org/classroom-activities

American Museum of Natural History
https://www.amnh.org/explore/curriculum-collections/dinosaurs-activities-and-lesson-plans

Smithsonian Museum of Natural History
http://qrius.si.edu/teachers/online/science-teaching-resources/fossils-preparation-field-museum
http://qrius.si.edu/teachers/online/science-teaching-resources/mass-extinction-large-dinosaurs
http://qrius.si.edu/teachers/online/science-teaching-resources/global-change-ocean-fossils

National Geographic's Sea Monsters
https://www.nationalgeographic.org/education/sea-monsters-education/

Reference Sites Pertaining to the Savage Ancient Seas:

Oceans of Kansas
http://oceansofkansas.com/

Kansas Geologic Survey
http://www.kgs.ku.edu/Extension/KSfossils.html

The Plesiosaur Directory
http://plesiosauria.com/

The Paleontology Portal
http://paleoportal.org/

Deep Time Maps
https://deeptimemaps.com/western-interior-seaway-thumbnails/

Wikipedia WIS Article
https://en.wikipedia.org/wiki/Western_Interior_Seaway

Puzzle Generator (word-finds, crosswords and more):

Discovery Education Puzzlemaker
http://puzzlemaker.discoveryeducation.com/

SAVAGE ANCIENT SEAS

A LETTER FROM THE EXHIBIT CREATOR

Above: *Triebold Paleontology, Inc. is headquartered in the Rocky Mountain Dinosaur Resource Center in Woodland Park, Colorado.*

Below: *Exhibit creator, Mike Triebold works in the field to carefully recover new fossils from the Cretaceous fossil sea beds outcropping in Western Kansas.*

Photo by KRISTY MANN

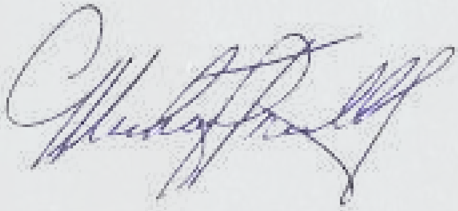
I vividly remember the moment in my youth that my own interest in learning and science was ignited. The sight of a fossil mosasaur skeleton in the museum at the South Dakota School of Mines and Technology made the connection for me between the fossils I had observed while doing chores around the family ranch and the rich natural history of our world. My desire to kindle that passion for learning and science in others is why I build a museum and this traveling exhibition featuring the same sorts of dinosaur-aged fossil skeletons that blew my own young mind so long ago.

Since 1989, Triebold Paleontology, Inc. (TPI) has been providing fossil skeletons, skeleton casts, and many paleontology and exhibit-related services to museums, universities and attractions the world over. Collaboration with major institutions allows us to bring to our exhibits, some of the most extraordinary and unique fossil cast skeletons displayed anywhere. My staff and I spend months in the field each year prospecting for and excavating new specimens which are then brought back to our museum laboratory to be stabilized and restored. The best and most scientifically important of our finds are molded and cast to be made available for purchase by other museums and are incorporated into our own exhibits, including the traveling exhibition this resource accompanies.

Our public museum, the Rocky Mountain Dinosaur Resource Center (RMDRC.com), resides in Woodland Park, Colorado, not far from Pikes Peak. It is open year-round serving families of tourists and school groups from around the region. Should you find yourself in our region, I invite you to stop by and take a guided tour!

Since you are viewing this Educator's Guide, there is a strong chance you are involved in the educational field as a professional or volunteer. I sincerely thank you for your service and for taking time to look through this guide. Your willingness to put the effort into getting the most out of this experience for the students you are working with is testament to your dedication to learning and meaningfully engaging the minds of the next generation. Keep up the good work!

Sincerely, Mike Triebold



President, Triebold Paleontology, Inc.


WE HOPE YOU ENJOYED
YOUR JOURNEY THROUGH
SAVAGE
ANCIENT
SEAS