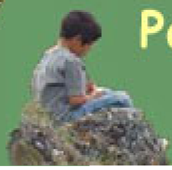
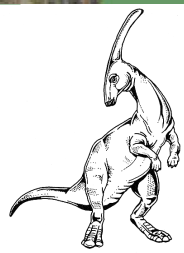
National Park Service
U.S. Department of the Interior



ParkWise
Your Alaska
National Parks
eClassroom

Photo Courtesy of Dr. Tony Fiorillo



Fossils in Time

Unit Overview

Students will learn about paleontology, the study of fossils and ancient life forms. This units covers geologic time and the different plants and animals that lived in the ancient past, as well as why they are important to study and preserve. Students will come along on a radio broadcast of a real life expedition to Aniakchak National Monument in Alaska where the ancient footprint of a hadrosaur was recently discovered.

This unit is designed for grades 5-9, although many of the activities can be adapted for both younger and older grades. Check out "Teaching Paleontology in the National Parks", for second and third graders.

Overview
Background
Unit Outline Paleontology is the study of ancient life. Fossils teach us about ancient life and the history of the earth. National parks preserve fossils so that we can study and learn from them.
Final Activity You are a paleontologist planning an expedition to uncover new evidence as to why the dinosaurs went extinct.
Final Activity Assessment
Instructional Resources
National Standards science and geography standards

Background

Our planet has a very long history, only a tiny fraction of which have humans been around to observe. How can we learn about the earth during times long past? Paleontologists are scientists who study the ancient past, using clues that have been left behind. These clues are preserved as fossils - evidence of ancient life forms that are no longer living, including dinosaurs, plants, insects, fish, birds, reptiles, and mammals.

Fossils are not found everywhere. They are found in particular types of rocks that were laid down during different times in the past. By studying both the fossils and the rocks where they have been found, paleontologists can teach us a great deal about what our planet was like and what lived there during those different times in the past.

The National Park Service preserves within its parks many areas where fossils are found. By creating parks, the Park Service can protect the rocks where the fossils are found and any other fossils that are still buried there. In this way, the fossil record is preserved for us to continue to study fossils, dinosaurs and the past of our shared planet earth. And the parks are open for all of us to visit and to learn from.

Scientists searching for dinosaurs in Alaska have found fossilized bones and even footprints left behind in ancient mud turned to stone. But nearly all of these discoveries were made on Alaska's North Slope. That changed late in the summer of 2001, when Texas paleontologist Dr. Anthony Fiorillo made a remarkable discovery in southwest Alaska. Join Doug Sneider as he interviews Dr. Fiorillo for the Arctic Science Journeys radio show.

The written transcript is also available.

Unit Outline

Focus Concept: Paleontology

Sub-concepts: fossils, geologic time, adaptations, extinction, preservation

Generalizations: Paleontology is the study of ancient life. Fossils are remnants of that ancient life and teach us about the history of the earth. National parks preserve fossils so that we can study and learn from them.

Information Sources: Introduction to Paleontology, The Geologic Time Scale, NPS Preserves Fossils, Fossils in Alaska National Parks, Alaska Dinosaur Discovery, Hadrosaurs, Alaska Paleontology

Guiding Questions and Readings	Critical Content (Students will know...)	National Standards Met	Skill Objectives (Students will be able to...)	Suggested Activity Lesson Plans
What is paleontology? What is geologic time? Background: Alaska Dinosaur Discovery radio show Introduction to Paleontology The Geologic Time Scale	... how to define paleontology. ... the different eras of geologic time. ... which life forms inhabited the earth during different eras and periods of the ancient past.	Science	... research facts about fossil remains and life forms. ...read and understand the geologic time scale. ...organize and analyze chronological information.	Activity 1: Paleontology Crossword Puzzle Students review their vocabulary of ancient time. Activity 2: When Did They First Appear? Students research when different organisms first appeared on earth.
What can we learn from fossils? All about Hadrosaurs	...how to define evolution, diversity, adaptation, and extinction. ...role of adaptations for organisms to survive in different environments. ...how to classify	Science	...use adaptations to classify organisms. ...make assumptions about organisms and their adaptations based on the fossil evidence.	Activity 3: Adaptations Students learn about the diversity of adaptations and their importance for survival.

Guiding Questions and Readings	Critical Content (Students will know...)	National Standards Met	Skill Objectives (Students will be able to...)	Suggested Activity Lesson Plans
	animals based on adaptive characteristics. ...the characteristics of hadrosaurs and how they are adapted to their environment.			
Where do you find fossils? Why should we protect fossils? NPS Preserves Fossils Fossils in Alaska National Parks Alaska Paleontology	...why fossils are important. ...what we can learn from fossils. ...what are threats to preserving fossils. ... the role of the National Park Service in preserving national treasures including fossils. ... some of the difficulties of finding and excavating fossils. ...that the Earth's surface has changed since ancient times ... in what types of rocks are fossils more likely to be found.	Science Geography	... use the Internet to do research. ...map the location of fossil parks in the United States ...build a timeline of fossils that are protected. ...read a geologic map. ...use maps and other reference information for scientific inquiry. ...plan the location of a scientific expedition.	Activity 4: Fossils Across America Students discover which geologic periods are best protected by national parks and where these parks are. Activity 5: Fossils in Alaska Word Search Students test their retention and vocabulary through a word search on paleontology in Alaska. Activity 6: Fossil Hunting in Alaska Students use a geologic map of Alaska to plan where to hunt fossils.

Guiding Questions and Readings	Critical Content (Students will know...)	National Standards Met	Skill Objectives (Students will be able to...)	Suggested Activity Lesson Plans
How do you search for fossils?	...what a fossil mold and cast are. ...the process of hunting fossils from start to finish.	Science	...how to create a print and a cast. ...describe the process of fossil hunting from start to finish.	Activity 7: Cookie Excavation Students will do a hands-on excavation of chips from different types of cookies. Activity 8: Print and Cast Students create their own print and cast. Activity 9: Follow a Fossil Students read online about the process from prospecting to exhibiting.
What next for paleontology?	...about how science and technology change over time. ...how researchers look for evidence to support theories.	Science	...research facts ...infer what evidence is necessary to support theories ...draw logical conclusions from evidence.	Activity 10: Fossil Futures Students research recent paleontology discoveries in the news. Final Activity: You are a paleontologist planning an expedition to uncover new evidence as to why the dinosaurs went extinct.

Introduction to Paleontology

What is paleontology?

Paleontology is the study of the ancient life forms that have inhabited our earth, and of the fossils that remain behind. Paleontologists, those scientists who study paleontology, are working to understand the types of plants and animals that have lived here, from the beginning of life on earth until the present. They study ancient ferns and fish, dinosaurs and bear-dogs, climates and continents. They search for fossils in rocks from all over the earth, discovering clues that will help them recreate what life was like in the ancient past.

What is a fossil?

Fossils are evidence of past life that can still be found today. Most often, fossils are remains that have mineralized, i.e., turned to stone. They can be the bones or teeth of saber-tooth tiger, ancient trilobite shells, the imprint of a fern frond, the footprint of a dinosaur, or petrified wood. By studying these fossils paleontologists learn about long-extinct organisms that inhabited the earth in ancient times, and about how they adapted to the environment they lived in.

What is geologic time?

Geologic time is a way of organizing the history of the planet earth. All time on earth is separated into 4 eras. Figure 1 shows the outline of geologic time. Scientists depict geologic time with the oldest at the bottom, just as it would appear in the rocks they uncover. The oldest rocks are at the bottom, and as newer rocks and sediments are added, they accumulate on top of the older rocks, layer by layer. For instance, if you were walking down into the Grand Canyon, you would start with the most recent rock formations, and the deeper you went down in, the older the rocks would be along the canyon walls. In the figure of geologic time, the first organisms appear at the bottom, and the most recent at the top.

What are the major eras of prehistoric life on earth?

The **Precambrian Era** was the time before life from the birth of the planet until first simple marine organisms appear in the fossil record. Because the algae and simple single and multiple-celled organisms of this time were all soft and microscopic, very little became fossils. Today we have relatively little evidence left from this time.

The **Paleozoic Era** is the age of ancient life. It starts with early sea life such as the trilobites and cephalopods and then is followed in later periods by the insects, fishes and the early amphibians and reptiles. Algae and plants grew on the land during this period, but the plants were relatively simple ferns and mosses. As plants began to produce more and more oxygen on the planet, animal life was able to grow and flourish in the new atmosphere.

The third era, the **Mesozoic Era** (meaning middle era of life) is the Age of the Ruling Reptiles. Three main groups of reptiles, the dinosaurs, crocodiles and pterosaurs were the dominant forms of life throughout the Mesozoic Era. The early mammals and birds appeared during this era but were not as common as the dinosaurs. Conifers spread across the land which was lush with giant ferns and other plants. A mass extinction, perhaps caused by a giant meteor striking the earth, occurred at the end of the Mesozoic Era, bringing in the Cenozoic Era, the age of recent life. We are still in the Cenozoic Era today. The Cenozoic Era is the age of mammals, birds, and the flowering plants and trees that are so familiar to us today.

While it is true that dinosaurs went extinct millions of years ago, they are actually quite a success story. They evolved into many different species with individual characteristics. They “ruled the earth” for more than 150 million years, that is longer than any other group of land animals. Not all of these species lived at the same time, many went extinct and many new ones evolved during their reign. They also gave rise to birds, which are still here with us today.

Dinosaurs have three characteristics that separate them from all other reptiles, living then or now. Dinosaurs hips, knees and ankles are built so that their legs come straight down under their body, unlike alligators for instance whose legs come out to the side and then down. Dinosaurs also have jaw muscles that reach all the way to the top of their skulls, and they have a ridge on their upper arm bone. Other reptiles may have some of these characteristics but only dinosaurs have all three.

Current theories about dinosaur extinction postulate that a massive asteroid hit the earth near the end of the Cretaceous period. At about that same time massive extinctions occurred of species living both on land and in the oceans. Fossils show that already by that time there were fewer and fewer species of dinosaurs in existence. Many scientists believe that the asteroid was a catastrophe that proved too much for the remaining species and brought the end of the Age of Dinosaurs. With time, the species of plants and animals that did survive recovered, and began to flourish, giving rise to new species some of which are here today.

After the dinosaurs went extinct, and the **Cenozoic Era** began, the birds and mammals began to thrive. The Cenozoic Era, meaning “the age of recent life”, is also considered the Age of Mammals. The birds and mammals, however, have changed a great deal during this era. At the beginning, mammals were mostly small creatures, eating plants and insects. With time they grew and diversified, including some very large animals like the woolly mammoths and giant sloths. As the plant eaters grew larger and more prevalent, so did the carnivores giving rise to saber-toothed tigers and the dire wolf. The great ice ages occurred during the Cenozoic Era, as well as the arrival of Neanderthals, and the early humans.

The Geologic Time Scale

The geologic time scale is a guide to the major eras and periods of the earth's history, from the very beginning of the planet to now. Only a tiny fraction of all of this time have humans been keeping written history. Scientists depict geologic time with the oldest at the bottom, just as it would appear in the rocks they uncover. The oldest rocks and fossils are laid down first. As newer rocks and sediments are added, they accumulate on top of the older rocks, layer by layer. The oldest fossils would be deeper and the youngest fossils closer to the surface. For instance, if you were walking down into the Grand Canyon, you would start with the most recent rock formations, and the deeper you went down in, the older the rocks would be along the canyon walls. In this table of geologic time, the first organisms to appear on earth will be at the bottom of the figure, and the most recent at the top.

Information compiled from Dixon, D., et al. 1988. The Macmillan Illustrated Encyclopedia of Dinosaurs and Prehistoric Animals. Macmillan Publishing Company, NY. NY, and the Geologic Time Scale, by the Department of Paleobiology, National Museum of Natural History: http://www.nmnh.si.edu/paleo/dino/timescal.htm

Geologic Time Scale

ERA	PERIOD	MYA*	LIFE AT THE TIME
Cenozoic Era *Age of Recent Life* or *The Age of Mammals*	Quaternary	0.01 - 5	Many mammals vanish during a vast ice age. Modern humans emerge and spread world wide. Species of plants and animals are similar to what we see today.
	Tertiary	5 - 145	The continents have moved to positions near where they are today. Flowering plants thrive and diversify. Vast forests exist in the tropical and temperate environments. Mammals spread and diversify.
Mesozoic Era *Age of Medieval Life* (Time of the Ruling Reptiles)	Cretaceous	145 - 200	North and South America begin to split apart. India is a separate continent, In the north are Euramerica and Asiamerica, with differing plant and animal species. Dinosaurs diversify and rule until the end of the Cretaceous period when they die out in a mass extinction along with many other marine and terrestrial species. Flowering plants appear, and insects begin to pollinate.
	Jurassic	200- 250	The supercontinent, Pangea, splits and the Atlantic Ocean appears separating Asia from the Americas and Africa. The age of the Ruling Reptiles is in full swing. Dinosaurs rule the earth and pterosaurs rule the skies. Dinosaurs are much larger and include giant herbivores. The first birds appear.
	Triassic	250 - 295	The first dinosaurs and mammals appear; they tend to be small and quick predators who run on their back legs. Cycads abound, seed ferns go extinct. Ammonites are common. Dinosaurs, crocodiles and pterosaurs emerge and diversify.
Paleozoic Era *Age of Ancient Life*	Permian	295 - 362	All land is in one giant continent, Pangea. Ferns, seed ferns and conifers abound. Insects diversify and spread. Many marine animals, including the trilobites, go extinct.
	Carboniferous	362 - 418	All land is in two great continents, in the north is Euramerica and Gondwanaland is in the south. The first reptiles appear on land, as do the first conifers and cycads. Giant ferns, horsetails, and club mosses are common. Trilobites become less common, graptolites go extinct.
	Devonian	418 - 439	Amphibians and insects begin to invade the land. The earliest ferns and plants with seeds appear. Fish abound.
	Silurian	439 - 490	The first life emerges on land, as plants and invertebrates. Fish develop and split into the bony fishes (teleosts) and the cartilaginous fishes (sharks and rays). Marine invertebrates continue to thrive.
	Ordovician	490 - 543	Corals, bryozoa and graptolites thrive along with the marine life of the Cambrian. The first true vertebrate fish discovered.
	Cambrian	543 - 2500	Marine life abounds, including red and green algae, brachiopods, gastropods, trilobites, sponges. The earliest fishes appear.
Precambrian Era (Time before Life)		2500 – 4600	Time from the birth of the planet approximately 4.6 billion years ago, until the first simple life forms appeared about 3.6 bya, including early bacteria and blue-green algae. The first multicellular animals, such as worms and jellyfish, appeared near the end of this era.

Activity 1
Paleontology Crossword Puzzle

Students complete a crossword puzzle of paleontology vocabulary.

Guiding Questions: What is paleontology? How has life evolved on earth?
Critical Content: Paleontology is the study of ancient life. There are four major eras of the earth's history and of life described in the Geologic Time Scale.
Grades: 3-6
Duration: 15-30 minutes
Group size: individuals or in groups of 2
Setting: classroom
Materials: Introduction to Paleontology and The Geologic Time Scale

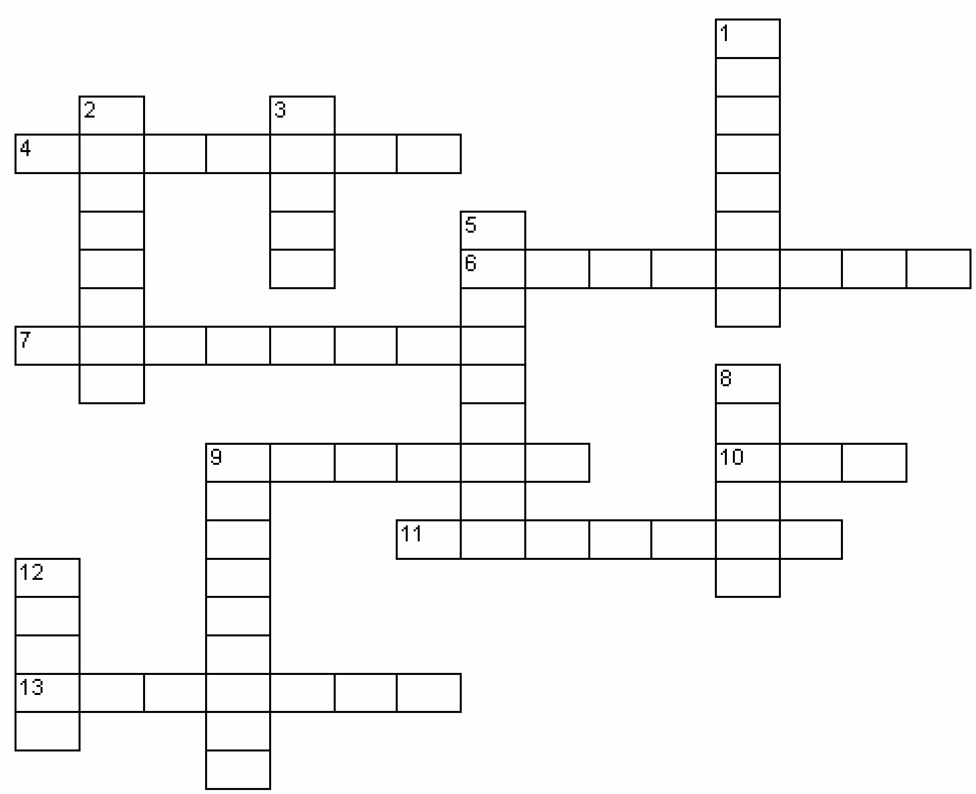
Before You Begin: Students should read Introduction to Paleontology and The Geologic Time Scale. If the readings are too difficult for younger students, explain the material to the class and give them the Geologic Time Scale as a reference.

Procedures: Complete the crossword puzzle below.

Discussion Questions:

1. What are some of the things that paleontologists can learn about the earth's history?
2. What are the four major eras of geologic time?
3. What are some of the things you most want to learn about dinosaurs and other prehistoric life?

The Paleontology Crossword Puzzle



Across:

4. When talking about how long ago the dinosaurs lived, we use this word to describe the numbers of years. It is part of the abbreviation "mya".

6. The earliest mammals evolved from these.

7. The period of the Mesozoic Era made famous in a movie about bringing dinosaurs back to life

9. Evidence of past life

10. The major unit of geologic time. There are four of these, including the Precambrian, Paleozoic, Mesozoic and the Cenozoic.

11. The study of rocks, including fossil remains.

13. The permanent loss of a species. When the species is gone forever it "goes ______".

Down:

1. Also known as the Age of the Ruling Reptiles.

2. The group of reptiles that ruled the land millions of years ago.

3. These flying animals are still common today. They evolved from dinosaurs.

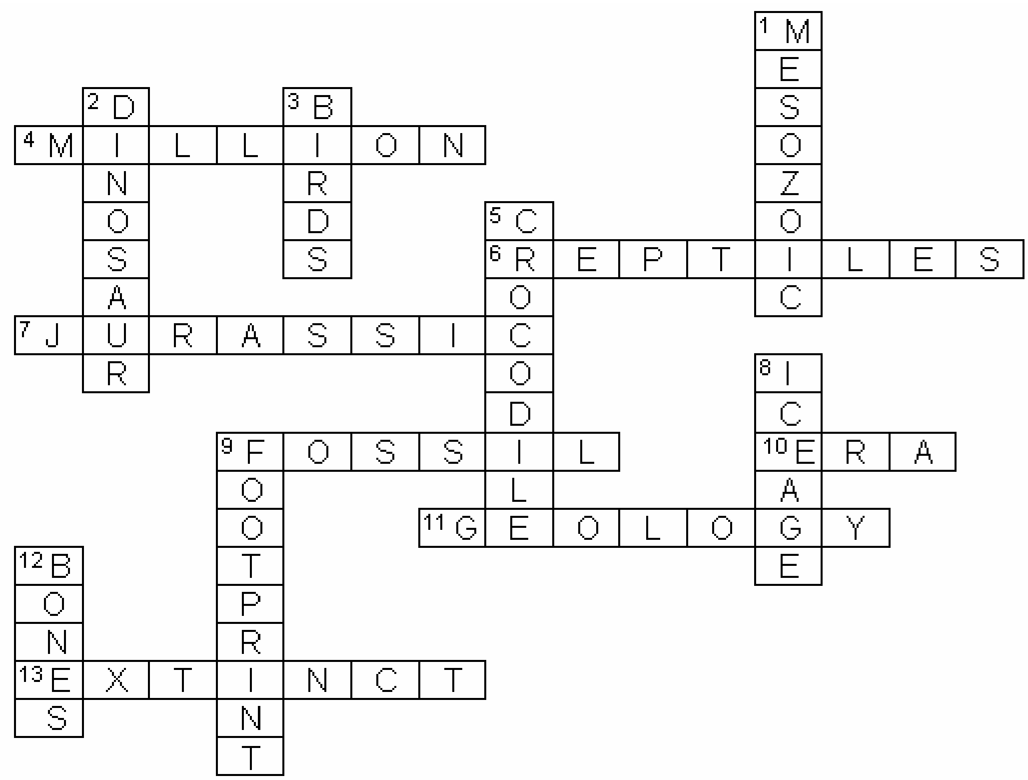
5. Along with the dinosaur and the pterosaur, this was one of the three Ruling Reptiles. Some species of this animal still live along waterways in Florida and Africa.

8. A time when the Earth got very cold and huge glaciers covered the north.

9. Evidence left behind where a dinosaur has walked. A hadrosaur left one of these behind in Aniakchak National Park

12. The parts of dinosaurs most often found as fossils. These help us to understand what dinosaurs may have looked like.

Answers to Activity 1
Paleontology Crossword Puzzle



Across:

4. Million – when talking about how long ago the dinosaurs lived, we use this word to describe the numbers of years. It is part of the abbreviation "mya"

6. Reptiles – the earliest mammals evolved from these.

7. Jurassic – the period of the Mesozoic Era made famous in a movie about bringing dinosaurs back to life

9. Fossil - evidence of past life

10. Era – the major unit of geologic time. There are four of these, including the Precambrian, Paleozoic, Mesozoic and the Cenozoic.

11. Geology – the study of rocks, including fossil remains.

13. Extinct – the permanent loss of a species. When the species is gone forever it "goes ______".

Down:

1. Mesozoic – also known as the Age of the Ruling Reptiles.

2. Dinosaur – the group of reptiles that ruled the land millions of years ago.

3. Birds – these flying animals are still common today. They evolved from dinosaurs.

5. Crocodile – along with the dinosaur and the pterosaur, this was one of the three Ruling Reptiles. Some species of this animal still live along waterways in Florida and Africa.

8. Ice Age – a time when the Earth got very cold and huge glaciers covered the north.

9. Footprint – evidence left behind where a dinosaur has walked. A hadrosaur left one of these behind in Aniakchak National Park

12. Bones – The parts of dinosaurs most often found as fossils. These help us to understand what dinosaurs may have looked like.

Activity 2
When Did They First Appear?

Students uncover the order in which different life forms appeared on earth.

Guiding Questions: What is paleontology? How has life evolved on earth?
Critical Content: Paleontology is the study of ancient life. There are four major eras of the earth's history and of life described in the Geologic Time Scale.
Grades: 4-8
Duration: 30-60 minutes
Group size: individuals or in groups of 2 or 3
Setting: classroom
Materials: Introduction to Paleontology and The Geologic Time Scale.

Before You Begin: Students should read Introduction to Paleontology and The Geologic Time Scale. If the readings are too difficult for younger students, explain the material to the class and give them the Geologic Time Scale as a reference.

Background: Many different plants and animals have inhabited the earth during its long history. Some of these appeared many millions, even billions, of years ago. Some appeared only recently. Some of these organisms, or types of organisms have gone extinct, some have evolved into different organisms, and others are still here today. To understand the changing environment of the earth, how these plants and animals evolved, and what the different eras and periods of the geologic time scale mean, it is helpful to understand when different organisms first appeared on the earth.

Materials:

The tables When Did They First Appear? and Progression of Life on Earth

Research resources: any resources that will help students research the appearance of different life forms, including reference books and the Internet.

Vocabulary:

Geologic Time
Era
Period
Fossil
Organism
Vertebrate

Procedures:

1. Students split into groups of one or more. Assign each of the organisms in the table below to a group. Groups may be assigned more than one organism. For older students, you can assign all of the organisms to each student to research independently.
2. For each organism, the group researches how long ago it first appeared on the earth. Use the Internet, the library, or any other appropriate resources to research the information.
3. As a class fill in the When Did They First Appear table.
4. Students fill in The Progression of Life on Earth table using the class generated research from step 3 above. Students may fill this in individually, in their groups, or as a whole class.
5. Review the Discussion Questions. Use them in open discussion for the whole class, or have students / groups answer them separately.

Discussion Questions:

1. Did dinosaurs and mammals ever live on earth at the same time?
2. Did dinosaurs and humans live at the same time?
3. In what order did reptiles, fish, amphibians, and mammals evolve? Why do you think that order is important?
4. Did animals first appear on land or in water?
5. Which appeared first in the water algae or animals? Which appeared first on land, plants or vertebrates? Why might this be?
6. Which have been around longer: insects or birds?
7. Which organism on the list is the oldest, and which is the youngest?

Activity 2
When Did They First Appear?

Plant or Animal	Millions of years ago
Dinosaurs	
Birds	
Plants on land	
Early mammals	
Sharks	
Amphibians	
Reptiles	
Fish	
Ferns	
Conifers	
Flowering Plants	
Tyrannosaurus	
Hadrosaurs	
Crocodiles	
Primates	
Humans	
Bacteria	
Trilobites	
Jellyfish	
Spiders	

Activity 2
When Did They First Appear?

The Progression of Life on Earth

ERA	PERIOD	MYA*	WHEN THEY FIRST APPEARED
Cenozoic Era *Age of Recent Life* or *The Age of Mammals*	Quaternary	0.01	
	Tertiary	5	
Mesozoic Era *Age of Medieval Life* (Time of the Ruling Reptiles)	Cretaceous	145	
	Jurassic	200	
	Triassic	250	
Paleozoic Era *Age of Ancient Life*	Permian	295	
	Carboniferous	362	
	Devonian	418	
	Silurian	439	
	Ordovician	490	
	Cambrian	543	
Precambrian Era (Time before Life)		2500 – 4600	

Hadrosaurs

What is a hadrosaur?

Hadrosaurs (Greek for "bulky lizard") are also known as the "duck-billed dinosaurs" because of their long flattened snouts. They first appeared during the Cretaceous period, near the end of the Age of Dinosaurs. Hadrosaurs were very common dinosaurs and fossils have been found throughout North America, Europe, and Asia. Based on their teeth, paleontologists believe that hadrosaurs were herbivores. Their teeth were mostly small and leaf-shaped, but there were plenty of them. Some hadrosaurs had almost 900 teeth! The hadrosaurs ranged in size from about 10 feet long (the size of a small car) to 40 feet long (the size of a school bus). They weighed up to 3 ½ tons, about as much as two cars!

The hadrosaurs' feet had three toes, covered in a hoof-like material. Hadrosaurs could walk (or run if a *Tyrannosaurus rex* was near!) on their large muscular hind legs, but may have occasionally used all four legs while grazing for food. Their long thick tails helped them balance while running. Without spikes, plates, or teeth to defend themselves, the hadrosaurs probably relied on keen senses of sight and smell, as well as their legs, to get out of trouble fast.

Detailed genealogy of the hadrosaurs

Dinosaurs fall into two major groups based on the type of hips they have. The Saurischia, or lizard-hipped, and the Ornithischia, or bird-hipped. Despite the names, there are dinosaurs that walk on two legs and ones that walk on four legs in both groups. The Saurischia species dominated during the Triassic Period, then the Ornithischia dominated later in the Cretaceous Period.

The Saurischia include two suborders: Sauropoda, or reptile-footed, and the Theropoda, or beast-footed. Different sources break Ornithischia into 3 to 5 suborders (the three suborders described here are as presented by the University of California, Berkeley, Museum of Paleontology). The Ornithopoda are bird-footed. The Thyreophora includes the plated Stegasauria and the armored Ankylosauria. The Marginocephalia, or fringe-headed, dinosaurs includes the horned Ceratopsia, and the bone-headed Pachycephalosauria.

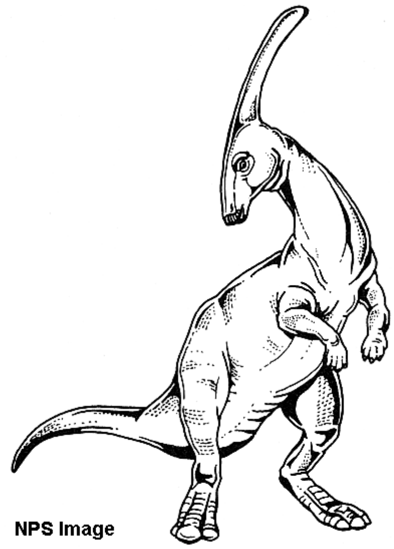
All of the Ornithischia were plant eaters who had evolved cheeks. Prior to these dinosaurs, the flesh along the side of the head ended at the back of the jaw.

Imagine the profile of a Tyrannosaurus; you can see all of the teeth, not just those in front. While this is effective for animals that use their jaws for killing, it is not effective for animals that chew plants for food. A lot of the food simply fell out the sides of their mouths. The Ornithischia were small to medium-sized dinosaurs (usually less than 30 feet long) but very successful. It was just at the beginning of the Cretaceous period that the number of species of flowering plants began to multiply dramatically. Perhaps because of these cheeks and the many new plant food sources, the Ornithischia flourished.

Order	Suborder	Family	Example Species
Sauroischia (lizard-hipped)	Theropoda (beast-footed)		Tyrannosaurus, Allosaurus
	Sauropoda (reptile-footed)		Brachiosaurus, Apatosaurus (Brontosaurus)
Ornithischia (bird-hipped)	Marginocephalia (fringe-headed)		Triceratops
	Thyreophora (armored)	Stegasauria (plated)	Stegosaurus
		Ankylosauria (armored)	Ankylosaurus
	Ornithopoda (bird-footed)	Hadrosauridae (duck-billed)	Maiasaura, Edmontosaurus, Lambeosaur
		Iguanodontidae (lizard-toothed)	
		Hypsilophodontidae (hypsilophus-toothed)	
		Hetereodontosauridae (different toothed)	

The Ornithopoda or bird-footed dinosaurs were one branch (suborder) of the Ornthischia that lived for some 140 million years, during the better part of both the Jurassic and the Cretaceous periods. Dinosaur species from other branches of the Ornithischia include the stegosaurus, ankylosaurus, and triceratops. The Ornithopoda were medium to large in size, by dinosaur standards. They walked on their back legs with three-toed, bird-like feet for which they were named. Four families make up the Ornithopoda, including the Iguanodons and the Hadrosaurs. The Iguanodon was one of the first dinosaurs to be discovered. A Hadrosaur footprint was recently discovered in Aniakchak National Monument and Preserve in southwest Alaska.

The Hadrosaurs are the members of the Hadrosauridae family, or the “duck-billed” dinosaurs that evolved probably in Asia during the Jurassic or early Cretaceous period, and by the late Cretaceous period had spread to Europe and North America as well. These were some of the later dinosaurs, living 80 million years after the Stegosaurus of the Jurassic period. They died out during the mass extinction that took place at the end of the Cretaceous period.


NPS Image

Hadrosaur Adaptations

Hadrosaurs had a wide duckbill like snout with no front teeth. They did have teeth further back for chewing vegetation. In fact, they had teeth that were continually being replaced. Their jaws were able to move up and down as well as side to side. These two adaptations, along with the cheeks common to all Ornithopoda, helped to make them particularly well adapted to chewing and eating even the toughest of the vegetation flourishing at the time.

The hadrosaur family consists of two subfamilies, the hadrosaurine duckbills and the lambeosaurine duckbills. The hadrosaurine had flat heads and bony ridges on their snout, whereas the lambeosaurine had high domed heads with hollow air passages in crests atop their heads. The lambeosaurine evolved in North America and have so far only been found there. The hadrosaurine were very successful, long-lived and were some of the last dinosaurs before the mass extinction at the end of the Cretaceous period. Common hadrosaurs include: Hadrosaurus (bulky lizard), Edmontosaurus (Edomonton lizard), Maiasaurus (good mother lizard), Lambeosaurus (Lambe's lizard).

Hadrosaurs might have roamed the earth in giant herds and so have been called the "cows of the Cretaceous." One fossil site found the bones of over ten thousand hadrosaurs, clearly a very large group! Hadrosaurs were likely a favored food of the *Tyrannosaurus Rex, which* lived at the same time. Hadrosaurs had powerful back legs and smaller front legs. They probably grazed on all fours, but ran (or fled) upright on their back two legs.

Nests of some species of hadrosaurs have been found, including a parent dinosaur sitting on a nest of eggs. Paleontologists discovered a particularly interesting Maiasaura (a dinosaur in the hadrosaurine subfamily) nesting area in Montana in 1978. The site showed that the mother made a crater-like nest with the eggs carefully arranged in a circular pattern. Several nests were grouped together showing that they were social animals, and the females were nesting in groups. Along with the mothers were Maiasaura of various ages, young ones, hatchlings, and intact eggs. This is fossil evidence that Maiasaura mothers cared for their young, rather than leaving the babies to hatch and grow on their own.

Some hadrosaurs, called Lambeosaurs, had large crests on the tops of their heads with built-in air passages. These air passages in Lambeosaurinae crests are a matter of speculation for scientists. Scientists think that Lambeosaurs could blow air through their crests, making tuba-like noises. Maybe they used these sounds to warn other members of the herd or as a mating ritual. Some of these air passages were quite large and connected with the hadrosaur's nasal passages but did not connect directly to the outside. The theory that most scientists now ascribe to is that the Lambeosaurinae used these as resonating chambers to make very loud, deep sounds that would carry far. In other words, they might have used them a bit like megaphones to call to others in their herd, to keep track of one another, or to attract mates or to warn of predators. The crests themselves are large and unusual looking, and another theory is that they used these crests to attract a mate, just like peacocks use their fancy feathers.

Activity 3
Adaptations

Students learn about the diversity of adaptations and their importance for survival

Guiding Questions: What are adaptations? What is diversity? How has life evolved on earth? How do we classify life on earth?
Critical Content: Adaptations are critical to the survival of life on earth. Different organisms have different adaptations, leading to diversity. We use adaptations to classify life forms.
Grades: 4-8
Duration: 60 minutes
Group size: individuals or in groups of 2
Setting: classroom
Materials: Hadrosaurs

Before You Begin: Students should read Hadrosaurs. If the readings are too difficult for younger students, explain the material to the class.

Background: Fossils help us to learn about the adaptations of animals that have long since gone extinct. By examining their adaptations, we can learn more about the diversity of life and what the earth once looked like. In this lesson, students will learn about adaptations, what kinds of conclusions you can draw from them, and how the diverse life forms are classified using these adaptations.

Materials:

- Hadrosaurs
- Adaptations Worksheet

Vocabulary:

- Adaptations
- Physical adaptation
- Behavioral adaptation

Diversity
Evolution
Classification
Extinction

Procedures:

1. Students split into groups of one or more.
2. Each student or group should complete the Adaptations worksheet on hadrosaurs
3. As a class, review the Discussion Questions.

Discussion Questions:

1. List all of the structural adaptations the students wrote down. How many different adaptations did they come up with. How did their answers vary for how these adaptations helped them to survive?
2. Compare the different answers to how the behavioral adaptations helped the hadrosaurs to survive.

Activity 3
Adaptations Worksheet

Adaptations are changes in a plant or animal that help it to survive. In animals, adaptations can be:

- **structural** - how the body is formed or shaped. Fins and legs are two different structural adaptations.
- **physiological** - how the body works. Cold-blooded and warm-blooded are two different physiological adaptations.
- **behavioral** - what the animal does, such as hibernating in the winter.

1. List 3 structural adaptations of the hadrosaur that paleontologists have learned from fossils and explain how each would help it to survive.

    1. ____

       ____

    2. ____

       ____

    3. ____

       ____

2. Paleontologists have also discovered that hadrosaurs were social animals by uncovering fossil evidence of at least two behavioral adaptations. Some hadrosaurs lived in large herds and so have been nicknamed the "cows of the Cretaceous". A fossilized Maiasaura nesting area showed that they nested in groups and cared for their young even after they hatched. For each behavioral adaptation, explain how you believe it helped the hadrosaurs survive.

   Living in groups ____

   ____

   Caring for their young ____

   ____

Diversity is the variety of different living things. The more different kinds of plants and animals the more diverse is the ecosystem. To understand the diversity of life on earth, we need to understand the similarities and differences between living things. Species become more diverse by acquiring new adaptations. Species are classified based on their adaptations. A classification helps us to organize and understand the similarities and differences between organisms and to chart the diversity of life.

1. All dinosaurs have three things in common. What are they? (Refer to the Introduction to Paleontology if you need to).

___

___

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2. All dinosaurs can be placed into two groups, or *orders*. What are the two groups, and what is different about them?

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3. All of the dinosaurs of the order *Ornithischia* had evolved an adaptation important for eating that paleontologists believe helped them to be very successful. What was that adaptation and why was it important?

___

___

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4. The order *Ornithischia* has three suborders. One suborder is called *Ornithopoda*. They were named for the type of feet they had. What did their feet look like, and how did they walk? Did the other suborders of *Ornithischia* have the same type of feet or walk the same way?

___

5. *Hadrosaurs* are a family of *Ornithopoda*. They *Hadrosaurs* were duck-billed with no front teeth. They include the *Maiasaur*, the *Edmontosaur*, and the *Lambeosaur*. They had at least 2 further adaptations for eating. What were they?

6. The Lambeosaurs had an intriguing adaptation to their heads that does not seem to be for eating. What was it, and what do you think it was for?

7. What else have paleontologists learned about what the hadrosaurs looked like?

8. You have now listed many of the adaptations used for classifying hadrosaurine dinosaurs. Looking at the classification table, what adaptations would the *Hadrosaurs* have in common with the *Sauropoda*? What would be different? (Hint: don't forget to start at the top).

9. What would the *Hadrosaurs* have in common with the *Hypsilophodontidae*? What adaptations would the *Hadrosaurs* have that the *Hypsilophodontidae* would not?

____

____

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Populations and Ecosystems: Populations are all of the individuals of a species that live in a particular time and place. Different populations and the environment they live in together make up the ecosystem. Populations can be understood by what their role is in the ecosystem.

1. Based on the adaptations discovered in the fossil record, what role did the hadrosaur play in the ecosystem?
   a) Carnivore - hunts and eats meat
   b) Herbivore - eats plants
   c) Scavenger - eats already dead meat
   d) Decomposer - helps to decompose dead plants and animal

2. For the ecosystem that *Hadrosaurs* lived in, we know three levels of the food web (who eats what). Level one are the plants that get their energy from the sun. Are *Hadrosaurs* level two or level three? What famous dinosaur occupies the other level?

   (1) **Sunlight** is absorbed by (2) **Plants** which are eaten by
   (3) ______________ which are in turn eaten by (4) ____________.

3. What type of environment do you think the hadrosaur lived in? Why?
   a) Ocean b) Desert c) Prairie
   d) Thick Forest e) Mixed trees and grasslands f) Mountain tops
   g) Glaciers

4. Do you think *Hadrosaurs* populations were small or large? What evidence do you have?

____

____

____

National Parks Preserve Fossils

Why should the National Park Service preserve fossils?

The mission of the National Park Service is to preserve America's special places for all Americans, including our future generations. This mission includes allowing people to come visit, enjoy and learn from these places, while preserving the resources that help to make these places so wonderful. The National Park Service protects wild and scenic rivers, mountains and glaciers, caves and canyons; it protects famous homes and battlefields of historic past, and it protects sites that contain keys to our distant, prehistoric past. Among these are sites containing the remains of early human cultures and sites containing fossils of ancient plants and animals that lived and died millions of years before the first humans set foot on earth.

Fossils are the evidence of life in the past. They may be the shells of marine life from ancient seas, the bones of a mastodon, petrified trees from a prehistoric forest, or the print of a dinosaur. Each and every fossil represents information about the ancient past that can never be revisited. We can only study the past through the evidence we see today, such as fossils and geologic formations. The fossils we find today can never be replaced. Once they are lost or destroyed, they are gone forever. Fossils are American treasures, and the National Park Service has many parks that are dedicated to preserving them.

The diversity of the fossil record in the National Park System is great. It includes microscopic organisms representative of some of the earliest life on the planet from the Precambrian to the bones of mammoths that lived during the Pleistocene. Eight National Park System units were established specifically for the protection of important fossils, but the geologic history of plants and animals is preserved in as many as 146 units. Plant remains may be represented by pollen, algae mounds called stromatolites, impressions of leaves, or huge petrified tree trunks. Fossils of invertebrate and vertebrate animals occur in parks and include shells, bones, and teeth. Many times the evidence of past life is based on trace fossils such as dinosaur tracks, burrows of extinct bear-dogs, eggshell fragments, or the dung of the giant ground sloth. Each type of fossil in its own way contributes to an understanding of the history of life on Earth.

The National Park Service preserves these treasures of the past so that they may be enjoyed by all, now and in the future. Unfortunately, not every person is able to visit all of the national parks. The National Park Service is dedicated to educating the public about these resources, so that they might appreciate and enjoy them, even if they cannot visit them directly.

Why should we create National Parks instead of just putting fossils in museums?

Many natural processes are constantly eroding rocks and exposing buried fossils. This erosion may be physical like rain, running streams streams, the seasonal freezing and thawing of rocks, or wind. Although erosion is critical for the exposure of fossils, it can also eventually cause their destruction. The Park Service monitors the areas containing fossils to minimize their loss or destruction.

Anthropogenic (human) activities can also threaten fossils. Not all types of rocks are hard enough to withstand the impact of hiking. Many types of rocks that contain fossils easily break under the weight of footsteps. Park visitors who have left designated hiking trails may inadvertently damage fossils and increase erosion in fossiliferous areas. Occasionally, people have even intentionally vandalized the fossils.

Fossils that are preserved in national parks cannot be taken for private use. To collect fossils from a park, a paleontologist requires a permit from the park. Fossils collected from parks are usually placed in a museum where the public will still have the ability to come see and learn from them. In recent years, however, the illegal collection of fossils from public lands has increased. The unauthorized possession of fossils from parklands is subject to fines and other penalties.

By creating a national park in an area rich in fossils, we are preserving not only the fossils, but the environment of where the fossil was. There are usually other fossils in the same place that are protected. Not only fossils but the context in which they are found is important. The type of rock in which a fossil is preserved, its position in the sequence of rocks, its association with other fossils, and its geographic location provide important information for understanding the history of the specimen, and the ancient environment in which it lived. All of this information must be recorded at the time the fossil is collected. National parks protect the information about the environment that existed when the plant or animal died. Many questions can only be answered by protecting the area where a fossil is found:

- How old is the fossil?
- What other plants and animals lived at the same time?
- What kind of habitat did the organisms live in? Was the environment ocean, grasslands or forest?
- Was the earth warm or cold? Wet or dry?
- What types of adaptations might organisms have needed to live in this habitat?

- What theories can we develop about the why animals bodies were shaped as they were? How might their anatomy have been an adaptation to their habitat?
- What can we learn about how the ecosystems functioned?
- How have plants and animals changed over time?
- How has the earth changed over time?

With time, the tools and technology available to paleontologists improves and scientists can learn more from a site today than they could 30 years ago. We assume that 30 years from now, scientists will be able to learn even more from the sites than they can today. By preserving these areas, scientists can come back to a fossil bed and learn more answers to the questions listed above. If the area is not protected, we cannot know today what information may be lost tomorrow. A great deal about the history of life remains buried in the Earth. The fossils throughout the National Park System play an important role in the telling of that story.

Parks protect more than the fossil remains of species that went extinct in prehistoric times, parks also protect species that are endangered today. Many species are threatened with extinction in the United States and around the world. Many of these species live in habitat protected by the National Park Service. Our hope is that through the preservation efforts of the National Park Service and others, many of these species will survive, and we will not have only their fossils to look back upon.

Selected National Parks with Fossil Treasures

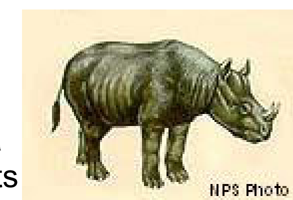
Agate Fossil Beds National Monument, Harrison, Nebraska

Geology Field Notes: http://www2.nature.nps.gov/grd/parks/agfo/index.htm

Agate Fossil Beds National Monument in Nebraska preserves a wealth of information about the "Age of Mammals" including the animals that lived there, the environment they inhabited, and how the climate has changed over time. About 19 million years ago, the area was covered with a savannah, somewhat like those of east Africa today. Herds of grazing animals and their predators once roamed the plains. To the west, the growing Rocky Mountains started to block the warm moist air moving across the land. With time the plains became cooler and drier, and droughts became increasingly common. With less food and water, animals gathered at the remaining shallow waterholes. At one of these waterholes, hundreds of animals died as the water ran out. Their skeletons were preserved under layers of sand, silt and ash carried by wind and streams when the waters later returned. The Monument preserves the remains of many different mammals, including numerous complete skeletons. Over time, the plains have been uplifted, with rivers such as the Niobrara River, cutting channels down through the soils and rocks, exposing these ancient layers and the fossils within.

Example animals from Agate Fossil Beds include:

Menoceras was a rhinoceros with 2 horns, but smaller than pony, that once moved across the plains in great herds.



Moropus was something like a cross between a horse and a giraffe. It was 7 feet tall at the shoulder, and heavily built. Its hooves had claws that might have been used from digging roots and bulbs or for defense.

Dinohyus was also 7 feet at the shoulder. This ferocious pig had large tusks, a massive head and long, slender legs.

Stenomylus were small, only 2 feet tall, looking like delicate deer. They also roamed the plains in large herds.

Badlands National Park, South Dakota

Geology Field Notes: http://www2.nature.nps.gov/grd/parks/badl/index.htm
Paleontology: http://www.nps.gov/badl/exp/home.htm

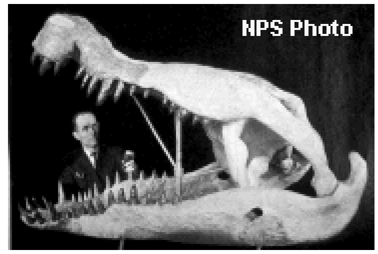
About 34 million years ago, during the Tertiary Period, the area that is now Badlands National Park was a broad marshy plain crossed by sluggish streams flowing out of the highlands of the new Rocky Mountains to the west. Ancestors and ancient cousins to the rhinoceros, horse, pig, cat and others roamed the plains. Countless animals lived and died on these plains. Remains left intact were buried by periodic floods and converted into fossils. Rocks laid down as sediments during the Eocene and Oligocene epochs are now laid bare, constituting one of the richest fossil beds known.

Big Bend National Park, Texas

Geology Field Notes: http://www2.nature.nps.gov/grd/parks/bibe/index.htm
Paleontology in Big Bend National Park:
http://www2.nature.nps.gov/grd/parks/bibe/paleo.htm
Dinosaurs, Pterosaurs and Crocodiles in Big Bend National Park:
http://www.nps.gov/bibe/dinosaur.htm

Big Bend displays dinosaur remains from the last 35 million years of the dinosaurs' existence, continuing uninterrupted from the Age of Reptiles into the Age of Mammals. The geologic layers help paleontologists learn the story of earth's history. The rocks chronicle times when the area was part of a deep ocean trough (500 – 300 mya), which then rose to become part of an ancient mountain system, which then eroded for some 160 million years, until 135 mya when a warm shallow sea (an extension of the current Gulf of Mexico) covered the area. The sea retreated 100mya leaving lowlands where crocodiles and turtles lived. Another period of uplift and erosion followed. Eventually similar plains mammals to those seen in Agate Fossil Beds and Badlands lived here. Ancient mountains and volcanoes, rivers and seas have all written their history in the geology of the park.

Big Bend's rocks are important to the study of how the earth changed between the Cretaceous and Tertiary periods – the time when massive extinctions occurred. One theory is that a massive meteor hit the earth, causing severe changes that the dinosaurs and other animals were unable to adjust to. Big Bend is relatively close to the area of the Yucatan where such a meteor might have hit the earth.



Big Bend includes fossils for the three major groups of ruling reptiles: dinosaurs, crocodiles, and pterosaurs. Over 90 dinosaur species, nearly 100 plant species, and more than two dozen fish, frogs, salamanders, turtles, crocodiles, lizards, and even early mammals have been discovered here, giving us one of the most complete pictures of a prehistoric ecosystem known anywhere on earth. Fossil remains include the jaw of a crocodile, *Deinosuchus riograndensis*¸ whose body was over 40 feet long, the wing bone of the largest pterosaur ever discovered, *Quetzalcoatlus northropi* with a wing-span approximately 35 feet long, and *Mosasaurus*, a 30-foot long reptile that lived in the sea, the skull of the triceratops-like *Chasmosaurus* the largest known skull of any land animal, and vertebrae from an *Alamosaurus*, over 100 feet long, as well as fossils of hadrosaurs, tyrannosaurs and others.

Dinosaur National Monument, Utah and Colorado

Geology Field Notes: *http://www2.nature.nps.gov/grd/parks/dino/index.htm*
Dinosaurs and Dinosaur National Monument: *http://www.nps.gov/dino/dinos.htm*

About 160 mya the area that is now Dinosaur National Monument was covered by ocean waters, the evidence of which is still in the rocks today. Not until about the midpoint of dinosaur history, about 145 million years ago, did a suitable habitat develop here: a low-lying plain crossed by several large rivers and many intermittent streams, where a variety of ferns, cycads, clubmosses, and clumps of tall conifers grew. In at least one spot, river floodwaters washed a great number of carcasses and bones onto a sandbar. There, mixed with the remains of turtles, crocodiles, and clams that lived in the river, the bones were preserved in the sand.

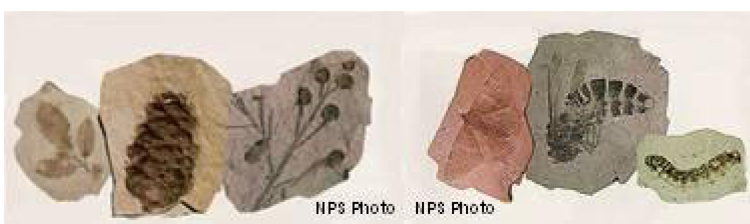
Fossils from several different dinosaur families have been found here. Sauropods were herbivores (plant eaters) that walked on all fours with long necks and tails; they were often huge. *Apatosaurus* (better known as *Brontosaurus)* was 70 to 75 feet long and weight about 34 tons. The only known *Apatosaurus* skull was found here. *Barosaurus* and *Diplodocus* were close relatives weighing in at 25 and 13 tons respectively. *Camarasaurus* was a much smaller cousin. The most complete sauropod skeleton found anywhere was found here of the *Camarasaurus*. *Stegasaurus*, another four-legged vegetarian is the largest and most famous of the stegasaurs. A juvenile was found here, about the size of a dog, although in adulthood it would have weighted from 2 to 5 tons. The ornithopods were two-legged plant eaters, of which a *Dryosaurus* and a *Camptosaurus* have been found.

Three predatory dinosaurs have been found, although their fossil remains are much less common here. *Allosaurus* is considered to be the most dangerous predator of the Late Jurassic period. Two skeletons and a near perfect skull have been found. *Ceratosaurus* is thought to be the only predatory dinosaur with a horn on its head. It also had a row of small bony plates down the center of its back and tail. *Ceratosaurs* may have hunted in packs to kill larger dinosaurs. The small *Ornithoestes* name means bird robber and it weighed only 200-300 pounds.

Florissant Fossil Beds National Monument, Colorado

Geology Field Notes: http://www2.nature.nps.gov/grd/parks/flfo/index.htm
Fossils of Ancient Lake Florrisant: http://www.nps.gov/flfo/ancientf.htm

The rich deposits discovered at Florissant Fossil Beds give us an unusually detailed look at what life may have been like in ancient North America during the close of the **Eocene Epoch**, about 35 million years ago. This was approximately 30 million years after the age of dinosaurs and at least 33 million years before the first humans appeared. During that time, Lake Florissant stretched 15 miles through an ancient forested valley. Lush ferns and shrubs thrived under a towering forest of redwoods, cedars, pines, and a colorful mix of maples, hickories, elms, and oaks. In this warm, humid climate, thousands upon thousands of insects crawled, flew, and buzzed about. Fish, mollusks, birds, and mammals inhabited the lake and its shores.



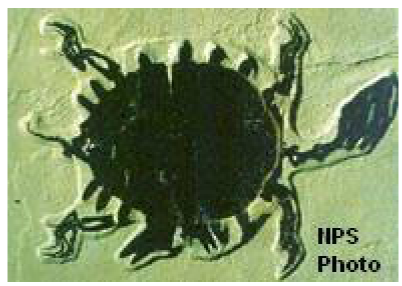
Exploding volcanic eruptions showered the area with millions of tons of ash, dust, and pumice. Caught in the cloud were insects, leaves, and fish; anything that could not escape died. Many fell to the lake bottom and were buried. These volcanic eruptions occurred over and over for perhaps as many as 700,000 years. Each time, fragments of life become trapped in a layer of volcanic sediments at the bottom of the lake. Eventually these sediments became finely layered shale and the buried plant and animal life became fossils. Even tiny creatures as fragile as butterflies have been preserved as fossils, including antennae, legs, hairs, and the pattern of their wings. Massive petrified redwood stumps are evidence that ancient plant life here had its giants, too. Paleontologists have collected more than 60,000 specimens from this park for museums and universities around the world.

Fossil Butte National Monument, Wyoming

Geology Field Notes: http://www2.nature.nps.gov/grd/parks/fobu/index.htm

Three ancient great lakes existed in the region of Wyoming, Utah, and Colorado 50 million years ago, one of which was Fossil Lake. A flat-topped remnant of rock (a butte) stands where the center of Fossil Lake once was and reveals a wealth of fossils in the ancient lake sediments. Fossil Butte National Monument preserves the butte and its invaluabe record of the past.

The numbers and variety of species found here is amazing: more than 20 kinds of fish, 100 varieties of insects, and an as yet uncounted number of plants. Paleontologists, have unearthed thousands of specimens during the past 100 years. Many billions more lie buried in the butte and surrounding ridges protected and preserved for future paleontologists to study. The fossils are remarkable for their detail. Many of the fish, for example, retain not only their entire skeletons, but their teeth, delicate scales, and skin as well. And perhaps most fascinating of all is the story the fossils tell of an ancient life and landscape.



The scene 50 million years ago, during the Eocene Epoch of the Cenozoic Era, was quite different from that today. Fossil Lake, 50 miles long and 20 miles wide, was nestled among mountains in a lush green forest of palms, figs, cypress, and other subtropical trees and shrubs. Willows, beeches, oaks, maples, and ferns grew on the lower slopes, and on the cool mountain sides was a spruce and fir forest. In and around the warm waters of the lake, animal life was diverse and abundant. A broad range of fish inhabited the tributaries, shallows, and deep water of Fossil Lake during its unusually long life of more than 2 million years. Gars, paddlefish, bowfins, and stingrays, though they may appear primitive to some, still survive today, as do herring, perch, and mooneyes. The lakeshore was alive with crocodiles and turtles; insects, dog-sized horses. Early primates inhabited the land. Birds and bats mastered the air.

Guadalupe Mountains National Park, Texas

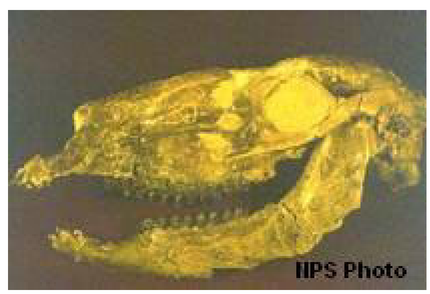
Geology Fieldnotes: http://www2.nature.nps.gov/grd/parks/gumo/index.htm
Geology: http://www.nps.gov/gumo/gumo/geology.html

Guadalupe Mountains National Park includes one of the finest examples of an ancient fossil reef, which formed about 250 million years ago. This was the time even before the dinosaurs, when the earth's diversify of life included amphibians, fishes, and insects as well as algae and fungus. The supercontinent of Pangaea had not yet broken apart. A vast ocean surrounded Pangaea with a narrow inlet connecting it to tropical inland seas including the Delaware Sea which was 150 miles long and 75 miles wide in what is now New Mexico and Texas, along the western edge of Pangaea, near the equator. During the late Permian Period, the Capitan Reef developed near the border of the Delaware Sea and grew for several million years until near the close of the Permian Period when the Delaware Sea's connection to the outer ocean closed off and the sea slowly evaporated away over thousands of years.

The Delaware Sea supported a rich diversity of Permian life. The reef sustained an abundance of organisms, including algae and sponges. Inhabitants of the rocky sea bottom were sea urchins, bivalve clams, and flower-like crinoids on long, slender stems. There were trilobites, a now extinct class of arthropods with segmented, three-lobed shells. Ammonoids and nautiloids, ancient cephalopods related to squid and octopi, propelled their chambered bodies through the sea in search of prey. Deeper on the reef, large, clam-like brachiopods clustered together clinging to the seafloor by a single fleshy muscle, called a pedicle. Tiny bryozoans formed in colonies that resembled delicate, lacy fans.

Hagerman Fossil Beds National Monument, Idaho

Geology Field Notes: http://www2.nature.nps.gov/grd/parks/hafo/index.htm
Paleontology and *Critter Corner* http://www.nps.gov/hafo/paleontology.htm



Hagerman Fossil Beds National Monument is internationally significant because it protects the world's richest known fossil deposits from the late Pliocene epoch. The plants and animals preserved here represent the last glimpse of time before the Ice Age, and the earliest appearances of modern plants and animals. The sediments span some 550,000 years, from 3.7 to 3.15 million years ago, revealing grassy plains dotted with ponds and forests that received more than 20 inches of rain and snow each year, over twice what it is today. Mastodons, sabre-tooth cats, beavers, muskrats, otters, camels, antelope, deer, ground sloths, hyena-like dogs, and fish, frogs, snakes, and waterfowl lived here. Scientists have found fossils from more than 140 animal species of both vertebrates and invertebrates. Eight species have not been found anywhere else, and 44 were found here first. The **Hagerman Horse**, *Equus simplicidens*, a zebra-like ancestor of the modern horse gives the park its name. Hagerman Fossil Beds is one of the few sites that preserves the number and variety of fossil evidence needed to study past climates and ancient ecosystems.

When significant environmental change occurs, most plants and animals have three options: adapt, migrate, or become extinct. The ancient ecosystem represented by fossil plants and animals illustrates each response as the region changed from a wetter grassland savanna to drier, high-desert conditions similar to those still seen today. Hagerman's beaver and muskrat and many birds **adapted** giving rise to similar species that are still here today. Llamas **migrated** to South America, while camels and horses traveled across the Bering Land Bridge to Eurasia. Ground sloths became **extinct**, along with mastodons and other large herbivores. With the disappearance of their primary prey, sabre-tooth cats and hyena-like dogs also became extinct.

John Day Fossil Beds National Monument, Kimberly, Oregon

Geology Field Notes: http://www2.nature.nps.gov/grd/parks/joda/index.htm
Paleontology: http://www.nps.gov/joda/paleo.htm

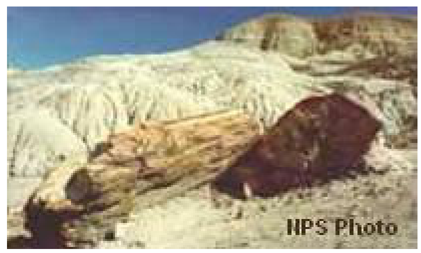
The John Day River Valley holds some of the richest fossil beds in the world, a record of remarkable continuity during the Tertiary Period of the Cenozoic Era, or the "Age of Mammals". While fossil beds that span five million years are rare, this valley records more than 40 million years of the diverse plant and animal life that existed here from 45 million to 5 million years ago. It is a record of such continuity and duration that scientists can test paleontological theories against the fossil record. Fossil beds contain vestiges of the actual soils, rivers, ponds, watering holes, mudslides, ashfalls, floodplains, middens, trackways, prairies, and forests. Fossil plants are generally more helpful than animals for understanding ecosystems. The John Day paleontology staff is working to identify the plant types over time and so they can reconstruct the ancient ecosystems and climates of eastern Oregon.

The climate here changed from warm and moist tropical and subtropical forests into cooler, drier grasslands over the course of 40 million years. The plant and animal life changed as well. The evolution of mammals can be followed here from early browsers and scavengers to dogs, cats, pigs, horses, camels, rhinos, and rodents. To these were added bears, bear-dogs, weasels, and a species of early elephant. Finally the latest formation includes horses, sloths, rhinos, camels, peccaries, pronghorns, dogs, bears, looking more like what we are familiar with today.

Petrified Forest National Park, Arizona

Geology field notes: http://www2.nature.nps.gov/grd/parks/pefo/index.htm
Trees to stone: http://www.nps.gov/pefo/treestostone.htm
Triassic reptiles and dinosaurs:
http://www.nps.gov/pefo/triassicreptilesamphibians.htm

During the Late Triassic Period, (225 million years ago) the area of Arizona that is now Petrified Forest National was located near the equator on the southwestern edge of the landmass known as "Pangaea". This tropical location resulted in a climate and environment very different from today, a large lowland basin with numerous rivers and streams flowing through. The lush landscape included coniferous trees up to nine feet in diameter and towering almost two hundred feet tall. Ferns, cycads and giant horsetails grew abundantly along the waterways. Crocodile-like reptiles, giant fish-eating amphibians and small dinosaurs inhabited the land and water. Petrified Forest National Park is one of the world's greatest storehouses of knowledge about life on earth when the "Age of the Dinosaurs" was just beginning.



Over time, as trees died, some were deposited on the flood plain adjacent to the rivers and others were buried in the stream channels. Most of the trees decomposed and disappeared. But a few trees were petrified, becoming the beautiful fossilized logs visible today. Most of the fossilized logs are from a tree called *Araucarioxylon arizonicum*. Two others, *Woodworthia* and *Schilderia,* occur in small quantities in the northern part of the park. All 3 species are now extinct.

Fossils of many different kinds of early dinosaurs have been found. Just a few are described here. *Chindesaurus* was an early primitive dinosaur. It was 8 to 12 feet long from head to tail, with sharp, sickle-shaped teeth indicating a meat diet. Lightly built with exceptionally long hind legs, it may have been one of the fastest land-dwellers in this area. This speed helped it overtake its prey. *Placerias gigas*, a large, bulky plant-eating reptile weighing up to 2 tons. It had strong but toothless jaws and probably lived on a diet of tough, fibrous plants. Large tusks may have been used to dig up roots and tubers for food. *Smilosuchus gregorii* may have reached 30 feet in length. They lived a crocodile-like life in the rivers and lakes preying on fish and smaller animals. Bony plates protected the body and tail.

Fossils in Alaska National Parks

What types of fossils have been found in Alaska?

More than a dozen dinosaur species have been found in Alaska, most from the time just before the massive extinction of dinosaurs at the end of the Cretaceous Period. The first dinosaur fossils found in Alaska were on the North Slope during the mid-1980s. The North Slope refers to the northern side of the Brooks Range, the most northern mountain range in Alaska. The fossils were of an *Edmontosaurus*, a duck-billed dinosaur of the hadrosaur family. *Edmontosaurus* was a large plant eater, about 10 feet tall and 40 feet long. It weighed about 3 tons. More recent fossils of other hadrosaurs, the *Troodon* and the *Dromaeosaurus* have been found along the Colville River of the North Slope. These dinosaurs were smaller than the *Edmontosaurus* and were carnivores.

Dinosaur footprints from the Jurassic Period have been found near Black Lake on the Alaska Peninsula. The tracks date back more than 140 million years, the oldest fossil evidence in Alaska, but scientists are not certain on the species of dinosaur that left them. In the Talkeetna Mountains of southcentral Alaska, the skull of an *Edmontonia* was found. *Edmontonia* was a four-legged herbivore with leathery and bony armor plates along its back. A hadrosaur skeleton, all but the skull, was found dating back to 90 million years ago. This is the oldest hadrosaur known in Alaska.

The bulk of the paleontology has been done on the North Slope. At least seven plant-eating dinosaurs have been found there. Hadrosaurs were large herbivores that walked on their back two legs and had a duck-like bill. Three different hadrosaur fossils have been found, including the *Edmontosaurus*, the *Kritosaurus*, and the *Lambeosaurid*. The *Pachyrinosaurus* and the *Anchiceratops* were both ceratopsians -- dinosaurs that walked on four legs, had large horns and horny plates on their heads. Hypsilophodontids were smaller herbivores that ran on two legs of which only *Thescelosaurus* has been found so far.

In addition, six different species of Theropods have been found on the North Slope. Theropods were mostly carnivorous. They ran quickly on their back legs to catch their prey, and killed them with sharp, serrated teeth. *Tyrannosaurus* and *Albertosaurus* were huge hunters 10 to 15 feet tall and equally long. The *Troodon* was smaller, only 6 feet tall, but had a larger brain and large eyes which may have been for hunting at twilight. Although only 4 feet high, *Dromaeosaurus* and *Saurornitholestes* may have been among the fastest and fiercest of the predators. *Pachycephalosaurus* was only 7 feet tall, it was an herbivore with a thick, domed skull. One theory for their thickened skulls is that they, like rams today, butted their heads in ritual combat.

Source Bureau of Land Management, Alaska Region: http://www.ak.blm.gov/ak930/akdino.html

Fossils in the National Parks of Alaska

Although there are only 16 national parks in Alaska (and several affiliated areas), they contain upwards of one-third of all the land in the national park system. They also include some of the more remote areas in the United States. Only a few of the parks have roads that lead to them. Only a tiny fraction of the park lands have established trails to use. The only tourist access to much of this land is by small airplane. Parks such as Denali, Kenai Fjords and Wrangell – St. Elias are along the road system. The parks of southeast Alaska, Klondike Gold Rush, Sitka and Glacier Bay are usually visited by boat – either by the Alaska ferry or the many cruise ships that tour that coast. Not only are they hard to get to, but they are extremely large.

The shear size and remoteness of these parks, makes paleontology research more than a little challenging. Think of looking for a fossil somewhere in a park the size of a small state, like Massachusetts or Vermont, that is very, very far away, and has no roads or and no trails. Don't forget, you can only do your field work during the few months of summer (not including spring or fall), because the rest of the year it is cold, dark, and mostly covered with snow. Despite all of this, paleontologists have found interesting fossils in the Alaska national parks. It is clear that there is much more to be learned than we already know. The process of discovery will be long and slow but exciting. There will still be plenty to discover when the students of today are the scientists of tomorrow!

Aniakchak National Monument

Present day Aniakchak National Monument, lies within a string of volcanic islands known as the Aleutian Islands. The area is known for extreme weather, stormy and cold, it has been little used by Native American or by European peoples. The land is rocky and only small plants live there. Much of the area cannot support trees, the soil is too shallow and the winds too strong. Most of the wildlife lives along the shores feeding on the plants and animals of the ocean rather than the land.

Rocks dating from the Late Jurassic period to the Eocene epoch (some x to y millions of years ago) can be found in Aniakchak. Researchers examining a section of late Cretaceous rock known as the Chignik Formation have found dinosaur footprints: the first evidence of dinosaurs in southeast Alaska. The Chignik Formation includes fossils from shallow marine environments in one section and fossils of life on land in another section. These fossils date from 77 to 68 million years ago, approximately the same time as dinosaur fossils found in northern Alaska.

Although parts of Alaska have moved through time, it is believed that these rocks and fossils were formed at the same latitude that the area is at now. In addition to the hadrosaur hand and footprints, researchers have also found fossil leaf litter and a standing forest. All of these together will help paleontologists reconstruct a picture of what the environment was like in Alaska some 70 million years ago. A forested environment with enough food to sustain dinosaurs weighing many tons that must have been quite different from that of today.

Bering Land Bridge National Preserve

The Bering Land Bridge was a stretch of land that connected North America to Asia, more than 13, 000 years ago. During the last ice age, much more of the earth’s waters were frozen as ice, and there was less water in the oceans. The sea level dropped and exposed the land between the continents. The land bridge was a migration route for plants and animals between the two continents, and the national preserve is an important source of information about the ice age.

At Bering Land Bridge National Preserve, researchers have found fossils from the Quaternary Period of the Cenozoic Era. The last great ice age was during this period. Scientists have found woolly mammoths, including their teeth and tusks and bone, and the remains of other animals such as ancient horses, bisons and even a prehistoric beaver dam. Fossils of ancient trees, beetles and marine life have also been found.

Another type of fossil record is buried pollen. Each year, the pollen from plants falls to the ground. If it falls in an area where sediment layers are forming, they are preserved within the sediments, whether they are soil or sedimentary rock.

Scientists take “cores” by putting a long hollow pipe straight down into the ground and pulling up a long, skinny plug of dirt or rock. By examining the pollen in the core, they can learn about the plants and therefore the environment and climate back through time. At Imuruk Lake in the preserve, researchers have been able to collect pollen cores dating back 100,000 years.

Katmai National Park

Although Katmai National Park is one of the most active volcanic areas in the world, with at least 14 active volcanoes, it is best known for its large population of brown bears which come to its rivers to feed on salmon. Katmai is less well known for its fossils, including a site along the shores of Naknek Lake. The site contains many remains of flowering plants, which first appeared sometime during the Cretaceous period. These plants did not diversify until after the dinosaurs had gone extinct. This site is likely to be only 50 millions years old, allowing researchers to examine yet another chapter in the changing paleoenvironment of Alaska.

Gates of the Arctic National Park and Preserve

Today, Gates of the Arctic is a maze of rugged mountains, glaciated valleys, and arctic tundra. It is inhabited by caribou, Dall sheep, wolves, and bears. Fossil deposits of its past, however, range from tiny invertebrates of the Devonian Period of the Paleozoic Era, some 400 mya, to Pleistocene remains of bison and mammoth less than 5 million years ago.

Fossils from the Paleozoic Era include marine invertebrates like coral, and variety of other small marine life have been found such as brachiopods and trilobites. From later in the Paleozoic, during the Permian period, scientists have found teeth from shark who once swam its waters. Many other marine fossils from the Triassic and Cretaceous periods of the Mesozoic Era have been preserved in limestone. Although the area has many high mountains today, it was obviously under the sea during the Paleozoic and Cenozoic eras. During the more recent past of the Pleistocene, however, the area was already above water and home to bison and mammoth and other mammals that roamed the northern reaches.

Yukon – Charley Rivers National Preserve

Yukon-Charley’s rich history is filled with warm, shallow seas, cold ocean bottoms, turbulent continental shelves, volcanic activities and continental collisions. The unusual and remarkable depositional history continues to baffle geologists. The rocks north of the Yukon River and overlying the Tintina Fault record, in almost unbroken succession, the history of the area from about 800 million years ago to the Cenozoic Era - about 40 million years ago - an incredible and perhaps unparalleled 760 million years.

The earliest animals were tiny, soft creatures from the Precambrian Era. Some were single-celled, you might not see them without a microscope. Later animals evolved bones and hard shells, which are more easily preserved as fossils. Finding the earliest organisms is difficult and exceedingly rare. In 1976, scientists discovered tiny one-celled organisms, and some multicellular jellyfish and flatworms in Yukon – Charley. The one-celled organisms are less than one-hundredth of an inch long and make the flatworms and jellyfish, about one-fiftieth of an inch long seem big in comparison. Not only that, they were found to be about 700 million years old. Making them some of the oldest fossils ever found.

The flatworm is particularly interesting because it looks to be an ancient ancestor to the group of microscopic animals that still live today, and are believed to be the type of animals that formed that line of animals which eventually evolved into the terrestrial animals – reptiles, amphibians, birds, and mammals.

Throughout the rest of the park, scientists have discovered other fossil beds that stretch all the way to the Pleistocene. These other fossils include marine invertebrates and shell fragments. The greatest amount of fossils are of plants, including pollen, fruit, seeds and wood. Because of its great size and remoteness, much still remains to be learned from the Yukon-Charley fossil deposits.

What is the next step for paleontology of national parks in Alaska?

Researchers will continue to visit the Alaska National Parks to determine what other fossil treasures there might be. By looking at sites around the state, it may be possible to develop a more complete picture of the environment, and its flora and fauna. Hadrosaurs as well as other herbivorous and carnivorous dinosaurs have been found in northern Alaska from the same time period. These finds show that the dinosaurs were year-round residents of these northern latitudes. Denali National Park and Yukon-Charley Rivers National Preserve both have sedimentary rocks from the same general time. By studying these and other parks in Alaska, scientists will continue to learn more about the earth, its environment and the species that lived here during those ancient times.

Activity 4
Fossils Across America

Students learn where we have national parks protecting fossils in the U.S.

Guiding Questions: What is paleontology? How has life evolved on earth?
Critical Content: Paleontology is the study of ancient life. There are four major eras of the earth's history and of life described in the Geologic Time Scale.
Grades: 4-8
Duration: 60 minutes
Group size: individuals or in groups of 2 or 3
Setting: classroom
Materials: NPS Preserves Fossils

Before You Begin: Students should read National Parks Preserve Fossils. If the readings are too difficult for younger students, explain the material to the class. Younger students might read What is the National Park Service? (from the National Parks as Treasure unit) to understand the role of NPS in preserving national treasures.

Background: National parks protect areas where fossils have been found. These fossils represent plants and animals that have existed over the history of the earth. They show how the earth has changed, and how the life on it has evolved. No one place, however, preserves the entire history. Putting together the history is like putting together pieces of a puzzle, where each park represents different pieces of the puzzle.

This activity demonstrates how paleontologists use fossils from different places to represent parts of the history, by putting them all together they can begin to understand the entire history.

Materials:

National Parks through Geologic Time table

Map of the United States (there are several different maps of the United States and national parks available in the maps section)

National Parks Preserve Fossils background reading material.

Selected National Parks with Fossil Treasures background reading material

Additional resources as needed for research, including the Internet

Vocabulary:

Geologic Time
Era
Period
Fossil

Procedures:

1. Students split into groups of one or more.
2. Each group selects a national park that preserves fossil remains to research. Students can either pick from the list in Selected National Parks with Fossil Treasures or visit the National Parks Service parks search by topic page. Students research the state where the park is located, the geologic time period(s) represented in the fossils it preserves, and list plant and animal species found in the fossil record at the park.
3. Together as a class fill in the table of National Parks through Geologic Time with the names of the parks that preserve paleontological treasures of each time period, and give examples of the types of plants and animals that have been preserved.
4. Mark each on the map provided, using different colors for different eras.
5. As a class, review the Discussion Questions.

Discussion Questions:

1. Which time periods are preserved, which are not preserved?
2. Which parks preserve ancient marine (saltwater) life, which preserve life in ancient freshwater lakes, which preserve ancient life on land?
3. Why is important to have more than one fossil park?
4. What can paleontologists learn from fossils?
5. List 3 reasons why it is important to establish parks around fossil finds?

6. What can we learn from studying the area where a fossil is found?
7. If you find a fossil in a park, what should you do?
8. Which of these parks would you most like to visit and why?

Activity 4
Fossils Across America

National Parks through Geologic Time

ERA	PERIOD	MYA*	NATIONAL PARKS AND SPECIES PRESERVED
Cenozoic Era *Age of Recent Life* or *The Age of Mammals*	Quaternary	0.01	
	Tertiary	5	
Mesozoic Era *Age of Medieval Life* (Time of the Ruling Reptiles)	Cretaceous	145	
	Jurassic	200	
	Triassic	250	
Paleozoic Era *Age of Ancient Life*	Permian	295	
	Carboniferous	362	
	Devonian	418	
	Silurian	439	
	Ordovician	490	
	Cambrian	543	
Precambrian Era (Time before Life)		2500 – 4600	

* MYA: millions of years ago


The United States
N
W
E
S
200 0 200 400 600 Miles

Activity 5
Fossils in Alaska
Word Search

Students complete a word search about paleontology in Alaska.

Guiding Questions: What are the national parks in Alaska? What fossils have been found there? Critical Content: The location and types of fossils in Alaska national parks. Grades: 3-6 Duration: 15-30 minutes Group size: individuals Setting: classroom Materials: Fossils in Alaska National Parks

Before You Begin: Students should read Fossils in Alaska National Parks. If the readings are too difficult for younger students, explain the material to the class and give them the Geologic Time Scale as a reference.

Procedures: Complete the word search below

Paleontology in Alaska Word Search

O	T	Y	R	A	N	N	O	S	A	U	R	U	S	E
H	K	R	A	L	C	E	K	A	L	S	I	T	K	A
A	E	R	P	T	E	R	O	S	A	U	R	T	Y	S
D	N	A	D	E	N	A	L	I	S	K	P	C	U	M
R	A	S	N	B	R	F	Q	U	K	A	L	O	K	Y
O	I	H	C	L	T	I	P	X	A	H	E	Y	O	E
S	F	M	E	S	O	Z	O	I	C	C	I	A	N	L
A	J	G	W	R	P	S	E	D	A	K	S	B	C	L
U	O	R	D	A	B	T	R	T	N	A	T	R	H	A
R	R	N	R	J	A	I	E	G	B	I	O	E	A	V
S	D	K	U	V	E	R	V	H	L	N	C	I	R	K
U	S	L	A	T	C	H	S	O	R	A	E	C	L	U
E	Y	C	A	R	N	I	V	O	R	E	N	A	E	B
Z	X	S	I	A	M	T	A	K	C	E	E	L	Y	O
E	M	T	E	N	O	T	S	E	M	I	L	G	A	K

Find these words:

Alaska – the northern-most, eastern-most, western-most and largest of the United States

Aniakchak – a national monument in Alaska where a hadrosaur footprint was recently found.

Carnivore – an animal that eats meat

Cretaceous – the last period of the Mesozoic Era. It was at the end of this period that the dinosaurs died out.

Denali – the national park with the tallest peak in North America.

Excavate – a fancy word for dig used by paleontologists. They do this to uncover fossils.

Glacier Bay – a national park where magnificent glaciers come down to meet the sea.

Hadrosaurs –common herbivores, known as the “cows of the Cretaceous”. A hadrosaur footprint was recently found in Aniakchak National Monument

Herbivore – an animal that eats plants

Katmai – In this national park and preserve, in 1912, Mount Katmai erupted in one of the most violent volcanic eruptions ever recorded.

Kenai Fjords – the deep fjords of this park are home to porpoises, whales, otters and sea lions.

Kobuk Valley – Native peoples have lived in the area now park of this park for more than 12,500 years, and still subsist there today.

Lake Clark – a national park and preserve home of several volcanoes and the 50-mile long lake for which it is named.

Limestone – a type of sedimentary rock found in oceans, and often containing fossils of ancient marine life.

Mesozoic – the geologic era also known as the Age of the Ruling Reptiles

Parks – land preserved for all Americans

Period – the units that make up a geologic era. The Jurassic period is known for its dinosaurs.

Pleistocene – it was during this epoch, 2 to 5 million years ago, that the great ice age occurred.

Pterosaur – a group of large flying reptiles that ruled the skies while the dinosaurs ruled the land.

Sitka – a national park where you can view historic totem poles carved by Tlingit Natives.

Sue – the name given one of the most complete Tyrannosaurus skeletons ever found.

Tyrannosaurus – a large carnivore of the Cretaceous period that probably ate hadrosaurs

Yukon Charley – short for Yukon-Charley Rivers National Preserve, home to endangered peregrine falcons.

Answers to

Paleontology in Alaska Word Search

	T	Y	R	A	N	N	O	S	A	U	R	U	S	
H	K	R	A	L	C	E	K	A	L	S	I	T	K	A
A	E		P	T	E	R	O	S	A	U	R		Y	S
D	N		D	E	N	A	L	I	S	K	P		U	
R	A				R				K	A	L	O	K	Y
O	I	H				I			A	H	E	Y	O	E
S	F	M	E	S	O	Z	O	I	C	C	I	A	N	L
A	J			R	P		E	D	A	K	S	B	C	L
U	C			A	B	T		T		A	T	R	H	A
R	R		R		A	I	E			I	O	E	A	V
S	D	K		V		R	V			N	C	I	R	K
U	S		A		C			O		A	E	C	L	U
E		C	A	R	N	I	V	O	R	E	N	A	E	B
	X		I	A	M	T	A	K		E	E	L	Y	O
E			E	N	O	T	S	E	M	I	L	G		K

Activity 6
Fossils Hunting in Alaska

Students learn how to decide where to look for fossils.

Guiding Questions: Where might fossils be?
Critical Content: Fossils are imbedded in rocks. Geologic maps show the different types of rocks and where they are.
Grades: 4-8
Duration: 60 minutes
Group size: individuals or in groups of 2 or 3
Setting: classroom
Materials: Fossils in Alaska National Parks

Background: Fossils are usually found in sedimentary rocks. These are the types of rocks that are created when sand, mud, silt, volcanic ash, or lime is deposited on the bottom of streams, lakes and oceans. These deposits cover up plants and animals on the bottom and eventually are turned to stone. Paleontologists look for fossils in areas where sedimentary rock from the ancient past has been exposed. This activity uses a map of sedimentary rocks of Alaska to help you plan where you might look for fossils in Alaska if you were coming for a dig.

Materials:

Geologic Time Scale

Map of sedimentary rocks and national parks of Alaska

Students should use additional resources including the Internet for their research

Paper and pencils

Alaska Paleontology

Vocabulary:

Geologic time
Fossil
Sedimentary rock
Silt
Lime
Paleozoic Era
Mesozoic Era
Cenozoic Era
Triassic Period
Jurassic Period
Cretaceous Period

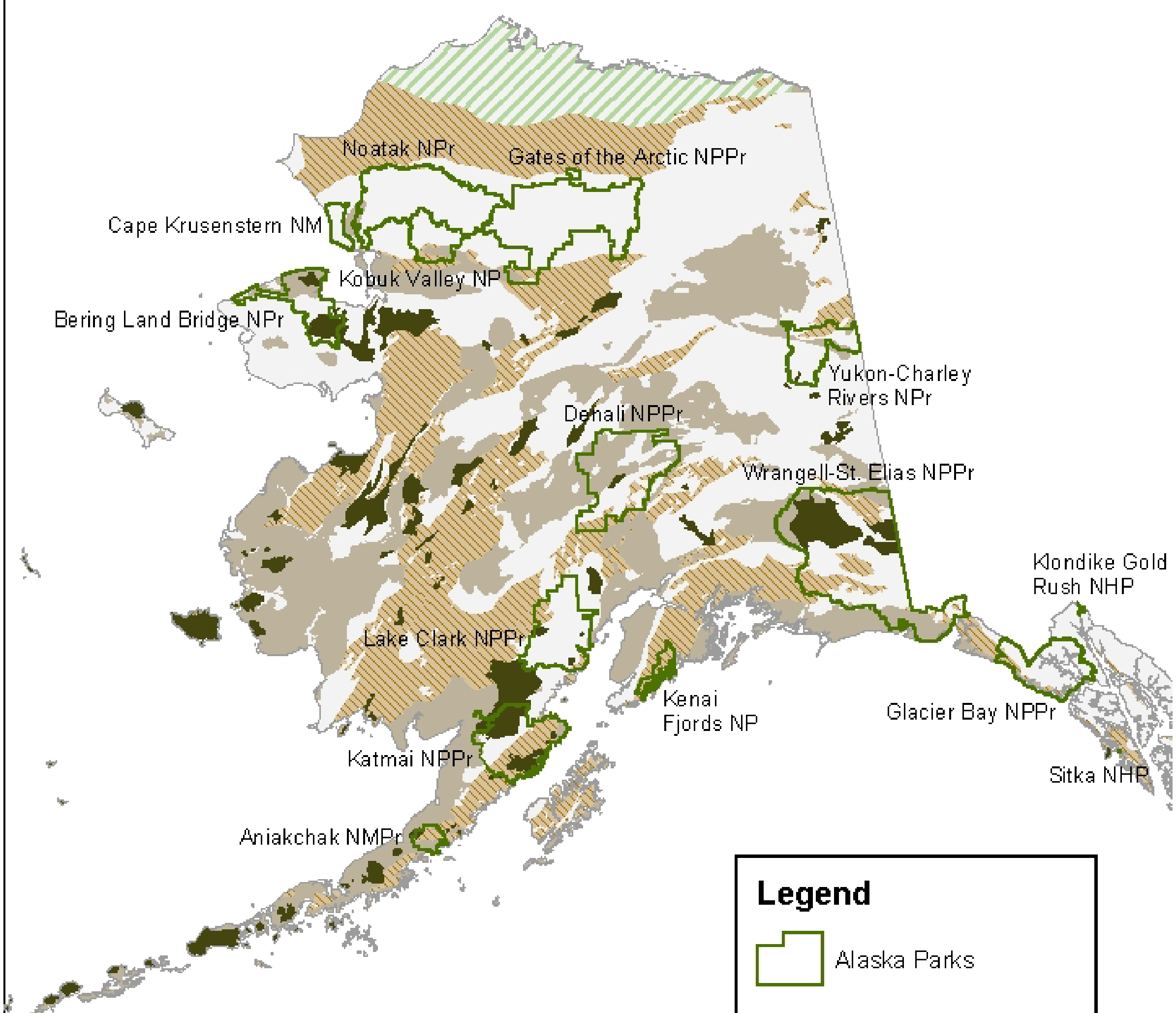
Procedures:

1. Students may work individually or in small groups. Give a copy of the attached map of geologic sediments and national park boundaries to each student or group.
2. Students use the map to decide which parks they would look in for fossils from each of the three eras: Paleozoic, Mesozoic and Cenozoic. What types of plants and animals lived during these periods?
3. Each student or group selects a dinosaur to research. Students should determine how many millions of years ago the dinosaur lived and which geologic period this was (Triassic, Jurassic, Cretaceous).
4. Students use the map key to determine how that time period is shown on the map. Students highlight on the map where in the national parks of Alaska they would visit to look for fossils from this dinosaur.
5. As a class, review the Discussion Questions.

Discussion Questions:

1. During which geologic time period did most students' dinosaurs live?
2. Which national parks of Alaska did students select for their fossil hunt?
3. If students had been told to select an extinct prehistoric *mammal*, which geologic era would be most likely to contain those fossils? Which national parks in Alaska have sedimentary rocks from that geologic era? Which national parks in Alaska have sedimentary rocks from both the "Age of the Ruling Reptiles" and the "Age of Mammals"?
4. Where else in Alaska might paleontologists look for fossils from the Jurassic and Cretaceous periods?
5. Review Alaska Paleontology and discuss what next for studying fossils in Alaska

Sedimentary Basins and National Parks of Alaska



Activity 7
Cookie Excavation

Students perform a "fossil" dig for chocolate chips. This activity has been adapted from the Badlands National Park activity.

Guiding Questions: How do you dig up a fossil?
Critical Content: Fossils are imbedded in rocks. What are the techniques for excavating a fossil from rock?
Grades: 3-6
Duration: 60 minutes
Group size: individuals
Setting: classroom

Background: Paleontology, like archaeology, involves fieldwork, including excavation -- the digging of fossils and ancient artifacts from the ground. The work is very painstaking and detailed, requiring patience, skill, and the ability to focus in on a small area for a long period of time.

Paleontologists typically use dental tools, like metal picks and scrapers, and brushes for their excavation work. They also use trowels when they are sure there are no small objects in an area that could be damaged. They may work years or even decades excavating a single site. Archaeologists have worked on a single site in Egypt since 1928 and they are still finding new information.

Materials:

Cookies - one of each type for each student:
- Hard chocolate chip cookie
- Soft chocolate chip cookie
- Hard raisin cookie
- Soft raisin cookie

Paper towels, 2 for each student

Toothpicks, 6 for each student

Vocabulary:

Paleontology
Fossil
Excavation

Procedures:

1. Give each student one of each type of cookie, two paper towels, and six toothpicks.
2. Start the students excavating in the hard cookies to extract the chocolate chips or raisins using only the toothpicks. If they break a toothpick so that it is no longer sharp, they can no longer use it. It must be discarded.
3. After 3 to 5 minutes, stop and find out if anyone was successful in extracting anything. As a class, review the Discussion Questions, below.
4. Have them excavate with the soft cookies using the same rules.
5. After 3 to 5 minutes, stop and find out if the students were more or less successful in extracting chips or raisins. Review the Discussion Questions again. How did the results differ between the hard and the soft cookies?

Discussion Questions:

1. What is the condition of the chips and raisins extracted? Were they whole or broken? Are there bits of cookies still clinging to them or are they relatively clean?
2. What was it like trying to remove the raisins and/or chips from the extremely firm cookie?
3. Did students get different results from the chips versus the raisins?
4. Has anyone used up all their toothpicks already?

Extension: Excavating raisins or chocolate chips from a cookie is similar to the work paleontologists do in the field, but working in a classroom is much different from excavating fossils on your hands and knees in the hot sun. To give your students a more realistic feel for paleontology fieldwork, bury some items in a school garden or other area where digging is acceptable, and have them excavate the items. This time, instead of toothpicks, provide them with screwdrivers and a garden trowel.

Activity 8
Print and Cast

Students make a mold of a "fossil print" and then create a cast from it. This activity has been adapted from Badlands National Park's Making a Fossil Cast.

Guiding Questions: What are casts and molds? How do you create a cast?
Critical Content: Fossils are imbedded in rocks. What are the techniques for excavating a fossil from rock?
Grades: 3-6
Duration: 60 minutes
Group size: individuals
Setting: classroom

Background: Fossils are not always the actual remains of the living organisms. Many fossils are just copies called imprints, molds or casts. Imprints are impressions made by organisms in soft mud that were preserved when the mud solidified. Imprints can be traces of an animal's activity, rather than its actual remains. The hardened tracks of animals or the burrows of prehistoric worms in solidified mud are examples of fossil imprints.

Molds are made when organisms are totally or partially buried in mud that hardens into rock. Over time ground water may dissolve the organisms, leaving cavities shaped like their bodies. Both imprints and molds are mirror images of the organisms.

If a mold was later filled with mud or mineral material, the hardened filling is called a cast. It is a reproduction that has the same outer shape as the organism. A cast looks like the organism itself, not like its imprint. Paleontologists make casts of fossil molds by filling them with liquids, such as plaster, that harden.

Materials:

Object to cast, a distinctly shaped object representing a plant or animal presence such as a small seashell, a pinecone, a student's finger, hand, or toe.

Modeling clay, enough so that students can create a form about twice the size of the seashell, finger or other object to be cast

Paper plate for each

Petroleum jelly

Paper cup, 7oz size

Plastic spoon

Plaster of Paris (available from craft or hardware store)

Tap water

Vocabulary:

Fossil
Mold
Cast

Procedures:

1. Give each student one of each type of cookie, two paper towels, and six toothpicks.
2. Start the students excavating in the hard cookies to extract the chocolate chips or raisins using only the toothpicks. If they break a toothpick so that it is no longer sharp, they can no longer use it. It must be discarded.
3. After 3 to 5 minutes, stop and find out if anyone was successful in extracting anything. As a class, review the Discussion Questions, below.
4. Have them excavate with the soft cookies using the same constraints and rules.
5. After 3 to 5 minutes, stop and find out if the students were more or less successful in extracting chips or raisins. Review the Discussion Questions again. How did the results differ between the hard and the soft cookies?

Discussion Questions:

The imprint in the clay and the plaster cast are both examples of how fossils form. Pressing the shell into the clay represents burying the shell in mud. In nature, the mud would have hardened into rock around the shell. Removing the shell from the clay represents how the shell dissolves over long periods of time, leaving a cavity called a mold in the rock. The mold produced is a mirror-image imprint of the shell's outside surface. In nature, this mold would have been filled with sediment, or small particles or rock and minerals that are deposited by water, wind, or ice that hardened into rock. The Plaster of Paris hardened, like the sediment, but in a much shorter period of time. The plaster is a replacement of the shell and is called a cast.

1. Might a paleontologist find a fossil mold or a fossil cast?
2. Which is created by the original plant or animal?
3. Which looks most like the original plant or animal?

Activity 9
Follow a Fossil

Students learn about the entire process of fossil preservation from field work to the museum display.

This activity is available from the Denver Museum of Nature and Science
http://www.dmns.org/main/minisites/fossil/index.html

Guiding Questions: What are the main steps of fossil collection?
Critical Content: Fossil collection includes prospecting, excavation, preparation, curation, research, and exhibiting.
Grades: 6-8
Duration: 60 minutes
Group size: individuals or groups depending on computer availability
Setting: classroom with Internet access

Background: Many museums support paleontology expeditions and fossil research. The paleontologist who discovered the hadrosaur print in Aniakchak National Monument, Tony Fiorillo, works for the Dallas Museum of Nature and Science. The Denver Museum of Nature and Science describes the process of finding new fossils and exhibiting them in a museum.

Materials:

Internet access

Vocabulary:

Fossil
Vertebrate

Invertebrate

Paleontology
Prospecting

Excavation

Preparation

Curation

Research

Exhibiting

Procedures:

1. Assign students into three groups: vertebrates, invertebrates and plants
2. Have students go to the Denver Museum of Nature and Science's Follow a Fossil website
3. Students will read about hunting vertebrate, invertebrate, and plant fossils depending on their group assignment. Students may read the pages alone or in groups.
4. As a class, review the Discussion Questions.

Discussion Questions:

1. What are the six steps of fossil hunting described by the Denver Museum of Nature and Science?
2. What do paleontologists do in each step and where do they do it: in the field or in the museum?
3. How do the steps differ for vertebrates, invertebrates and plants?

Activity 10
Fossil Futures

Guiding Questions: How does paleontology change over time? What new technologies are used? What new things are being discovered?
Critical Content: Science and technology are constantly changing. New technologies lead to new understandings. Scientific knowledge expands as we study.
Grades: 4-8
Duration: 120 minutes (homework)
Group size: individuals or in groups of 2 or 3
Setting: classroom

Materials:

Internet access

Vocabulary:

Technology
Science

Procedures:

1. Students split into groups of one or more.
2. Each student is to use the Internet to find a new discovery about paleontology. The discovery could be a recent fossil find, a new understanding about ancient organisms or ecosystems, a new technology that scientists can use to learn more about fossils or ancient ecosystems, etc.
3. Students write a short description of the discovery and why it is interesting. Explain any new techniques used in the discovery. Include pictures or diagrams to illustrate the discovery or the techniques.

Discussion Questions:

As a class review the the discoveries and the new things that scientists are still learning about the ancient past, and the techniques that they are using.

Some Suggested Websites:

Discover Magazine (http://www.discover.com)

MSNBC News site (http://www.msnbc.msn.com)

New York Times (http://www.nytimes.com)

Reuters News Service (http://www.reuters.com)

Scientific American (http://www.sciam.com)

Yahoo News (http://news.yahoo.com)

Final Activity

You are a paleontologist for the National Park Service. You have been asked to plan an expedition to uncover new evidence as to why the dinosaurs went extinct. Before you go, you must write a plan for your expedition that follows the outline below.

1. Write a brief outline describing your theory of why the dinosaurs went extinct. You can create your own theory, or describe a theory currently being tested by other paleontologists.
2. List some of the existing evidence that paleontologists have already found that supports your theory of why the dinosaurs went extinct.
3. To support your theory, you will be looking for new evidence in the fossil record. What are you going to look for, and why will that support your theory.
4. To which park are you going? What other fossils have been found there? Why do you think you will find fossil evidence there?
5. Outline how you will use geologic maps and other resources to plan where you are going to dig. What age and type of rock will you be excavating in?

Adaptation for the lower grades: Students write a short description of one theory of why dinosaurs went extinct, including a list of existing evidence that supports the theory, and appropriate maps, timelines or other graphics to illustrate the theory and evidence.

Assessment for the Final Activity

Criteria	Above Proficiency	Proficient	Not Proficient
Research & Gather Information	Collects a great deal of information--all relates to the topic	Collects some basic information--most relates to topic	Collects very little information--some relates to the topic.
Logic and Rationale	Offers clear and defensible reasons for choice of park to visit, including examples of previous finds. Describes in detail the type of fossil and characteristics they hope to find, and how these will answers extant questions.	Offers information which is gathered	Either gives too little information or deviates from the groups' task
Creativity	Original and thoughtful ideas. Illustrations portray the information in an original way. The illustration is original and the connection to the material is original.	Ideas are thoughtful and somewhat original. Illustrations are creative, but their means of portraying information is not.	Ideas are not original, presentation is not original Illustrations not original and are not effective at portraying information.
Presentation	Clear depiction and incorporation of many elements of natural history including geologic time, genealogy, adaptation, and environment. Effective and accurate use of writing conventions. Fluent and articulate writing. Effective organization and presentation with thoughtful information and strong supporting details. Graphics offer support of text.	Incorporates some of elements of natural history Effective and accurate use of writing conventions Presentation is organized and uses details well. Some graphics.	Presentation lacks organization. Writing conventions are not always followed. Presentation has little information with either no graphics or the graphics do not support the text.

Instructional Resources

National Park Service

Tour of Fossil Parks: http://www2.nature.nps.gov/grd/tour/fossil.htm

Teaching Paleontology in the National Parks, a curriculum for second and third grade teachers:
http://www2.nature.nps.gov/grd/edu/teaching_paleo_unit1.pdf

NPS Paleontology Homepage
http://www2.nature.nps.gov/grd/geology/paleo/index.htm

NPS Paleontology Newsletters
http://www2.nature.nps.gov/grd/geology/paleo/news/newsletter.htm

Park Geology Education links: http://www2.nature.nps.gov/grd/edu/ includes links to Intro to Fossils slide shows for second and third grades.

US Geologic Survey

USGS Geologic Glossary (simplified definitions for technical terms)
http://www2.nature.nps.gov/grd/usgsnps/misc/glossaryAtoC.html

Geologic Time (online edition) http://pubs.usgs.gov/gip/geotime/

Major Divisions of Geologic Time:
http://pubs.usgs.gov/gip/geotime/divisions.html

Index Fossils: http://pubs.usgs.gov/gip/geotime/fossils.html

Fossils, Rocks, and Time http://pubs.usgs.gov/gip/fossils/

Dinosaurs: Facts and Fiction http://pubs.usgs.gov/gip/dinosaurs/

Paleogeography http://pubs.usgs.gov/gip/continents/

Vertebrates - describes the evolutionary progression of vertebrates through geologic time, and how paleontologists infer past environments from the vertebrate fossils: http://geology.er.usgs.gov/paleo/vertebra.shtml

Alaska Museum of Natural History

Alaska Dinosaurs and Marine Reptiles: includes information on fossils, dinosaurs in Alaska, and several activities.
http://www.alaskamuseum.org/webed/dinosaurs/

University of California, Berkeley, Museum of Paleontology.

http://www.ucmp.berkeley.edu/index.html

Geologic Time Scale graphic – very nice and detailed :
http://www.ucmp.berkeley.edu/education/explorations/tours/geotime/guide/geologictimescale.html

Geological Time Machine - describes each geologic era and period.
http://www.ucmp.berkeley.edu/help/timeform.html

What killed the dinosaurs? - includes discussion on extinction, invalid hypotheses and current arguments.
http://www.ucmp.berkeley.edu/diapsids/extinction.html

Teaching Evolution - information on teaching evolution and the fossil record, with lesson plans and activities.
http://evolution.berkeley.edu/

Smithsonian Museum

Department of Paleobiology http://www.nmnh.si.edu/paleo/

Bureau of Land Management, Alaska

Dinosaurs on the North Slope of Alaska: includes information about fossil finds in northern Alaska, as well as rules for collecting fossils on public lands.
http://www.ak.blm.gov/ak930/akdino.html

Field Museum of Natural History¸Chicago Illinois

http://www.fmnh.org/

See Sue, the world's largest, most complete and most famous T. rex.
http://www.fieldmuseum.org/sue/default.htm

Explore expeditions@fieldmuseum™ and join the hunt for fossils in Wyoming. Sign up to receive emails from scientists in the field!
http://www.fmnh.org/expeditions

Denver Museum of Nature and Science

Follow a fossil – describes the process of fossil hunting from prospecting, excavation, preparation, curation, research, and exhibiting.
http://www.dmns.org/denverbasin2/fossil/index.html

Palaeontologia Electronica

Go to the Teacher Resources section for a variety of teach tools and links.
http://www.omnh.ou.edu/paleo/toc.htm

Zoom Dinosaurs

a comprehensive on-line hypertext book about dinosaurs of the Enchanted Learning Company.
http://www.enchantedlearning.com/subjects/dinosaurs/

National Education Standards - Generalized

Unit Sections:	
1	What is paleontology? What is geologic time?
2	What can we learn from fossils?
3	Where do you find fossils? Why should we protect fossils?
4	How do you search for fossils?
FA	Final Activity: You are a paleontologist planning an expedition to uncover new evidence as to why the dinosaurs went extinct.
National Science Standards	
National Geography Standards	

National Science Standards: (see Unit Sections)

go to detailed science standards

Content Standard A: Science as Inquiry **1, 2, 3, 4, FA**

Content Standard C: Life Science **2, FA**

Content Standard D: Earth and Space Science **1, 2, 3, 4, FA**

National Geography Standards: (see Unit Sections)

go to detailed geography standards

Element 1: The World in Spatial Terms **3, FA**

Element 2: Places and Regions

Element 3: Physical Systems

National Education Standards - Detailed

Unit Sections:	
1	What is paleontology? What is geologic time?
2	What can we learn from fossils?
3	Where do you find fossils? Why should we protect fossils?
4	How do you search for fossils?
5	What next for paleontology?.
National Science Standards	
National Geography Standards	

National Science Standards: (see Unit Sections)

return to generalized science standards

Content Standard A: Science as Inquiry

Grades K-4:

- Abilities necessary to do scientific inquiry:
  - ask a question about objects, organisms and events in the environment; **1, 2, 3**
  - plan and conduct a simple investigation; **3, 5**
  - employ simple equipment and tools to gather data and extend the senses; **4**
  - use data to construct a reasonable explanation; **1, 5**
  - communicate investigations and explanations; **1, 3, 5**

- Understanding about scientific inquiry
  - scientific investigations involve asking and answering a question and comparing the answer; **1, 2, 5**
  - scientists use different kinds of investigations; **2, 3, 4, 5**
  - simple instruments provide more information than using only senses; **3**
  - scientists develop explanations using observations and what they already know; **2, 5**
  - scientists make the results public; **2, FA5**scientists review and ask questions about the results of other scientists' work.

Grades 5-8:

- Abilities necessary to do scientific inquiry:
  - identify questions that can be answered through scientific investigations; **2, 3, 4, 5**
  - design and conduct a scientific investigation; **3, 5**
  - use appropriate tools and techniques to gather, analyze, and interpret data; **1, 2, 3, 5**
  - develop descriptions, explanations, predictions and models using evidence; **5**
  - think critically and logically to make the relationships between evidence and explanations; **2, 5**
  - recognize and analyze alternative explanations and predictions; **2, 5**
  - communicate scientific procedures and explanations; **3, 4, 5**
  - use mathematics in all aspects of scientific inquiry.

- Understanding about scientific inquiry
  - different kinds of questions suggest different kinds of scientific investigation; **2, 3, 4, 5**
  - current scientific knowledge and understanding guide investigations; **2, 3, 4, 5**
  - mathematics is important in all aspects of scientific inquiry;
  - technology used to gather data enhances accuracy and analysis; **5**
  - scientific explanations emphasize evidence; **1, 2, 3, 5**
  - science advances through legitimate skepticism, answering and querying others' work;
  - scientific investigations can result in new ideas or methods for study; **5**

Grades 9-12:

- Abilities necessary to do scientific inquiry:
  - Identify questions and concepts that guide scientific investigations; **2, 3, 5**
  - Design and conduct a scientific investigation; **2, 3, 5**
  - use technology and mathematics to improve investigations and communications; **5**
  - formulate and revise scientific explanations and models using logic and evidence; **2, 5**
  - recognize and analyze alternative explanations and models; **2, 5**
  - communicate and defend a scientific argument; **5**

- Understanding about scientific inquiry
    - scientists usually inquire about how systems function, concepts guide inquiry, history and knowledge influence design and interpretation; **2,**
    - scientists conduct investigations for a wide variety of reasons; **1, 2,**
    - scientists rely on technology to enhance the gathering and manipulation of data; **3**
    - mathematics is essential in scientific inquiry;
    - scientific explanations must adhere to criteria, including logic, consistency, etc. **2, 5**
    - results of inquiry - new knowledge and methods - emerge from different types of investigations and public communication between scientists;

Content Standard C: Life Science

Grades K-4:

- The characteristics of organisms
    - organisms have basic needs, the world has many different environments; **2**
    - each plant or animal has different structures that serve different functions in growth, survival, and reproduction;
    - behavior of organisms is influenced by internal and external cues;

- Organisms and environments
    - all animals depend on plants. Some animals eat plants for food; **2**
    - an organism's patterns of behavior are related to the nature of that organism's environment, when the environment changes, some organisms survive and reproduce, and others die or move; **2, 5**
    - all organisms cause changes in the environment where they live, some are detrimental, some are beneficial;
    - humans depend on their natural and constructed environments, humans change the environment;

Grades 5-8:

- Reproduction and heredity
    - reproduction is a characteristic of all living systems and is essential to the continuation of every species;

    - sexual reproduction includes egg and sperm and the transfer of genetic information;
    - every organism requires a set of instructions for specifying its traits;
    - hereditary information is contained in genes;
    - characteristics of an organism are a combination of inherited traits and traits from interactions with the environment;

- Populations and Ecosystems
    - a population consists of all individuals of a species that occur together at a given place and time; populations living together compose an ecosystem; **2**
    - populations of organisms can be categorized by the function they serve in an ecosystem; **2**
    - sunlight is the major source of energy for ecosystems; **2**
    - the number of organisms an ecosystem can support depends on the resources; **5**

- Diversity and adaptations of organisms
    - millions of species are alive today, they may look dissimilar, but the unity is apparent from their internal structures; **2**
    - biological evolution accounts for the diversity of species developed over many generations; species acquire many characteristics through biological adaptation; biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment; **2**
    - extinction occurs when the environment changes and the adaptive characteristics of a species are insufficient. **5**

Grades 9-12:

- Biological evolution
    - species evolve over time; **1, 2**
    - the great diversity of organisms is the result of evolution; **2**
    - millions of different species are related by descent from common ancestors; **1, 2**
    - biological classifications are based on how organisms are related, classification is hierarchical based on similarities; **2**

- Behavior of organisms
    - multicellular animals have nervous systems that generate behavior;

    - organisms have behavioral responses to internal changes and to external stimuli, behavior must be flexible to deal with uncertainty and change in the environment;
    - behaviors have evolved through natural selection;
    - behavioral biology has implications for humans, as it provides links to psychology, sociology and anthropology.

Content Standard D: Earth and Space Science

Grades 5-8:

- Earth's History:
    - the earth processes we see today, including erosion, movement of lithospheric plates, and changes in atmospheric composition, are similar to those that occurred in the past. Earth history is also influenced by occasional catastrophes, such as the impact of an asteroid or comet; **5**
    - fossils provide important evidence of how life and environmental conditions have changed; **1, 2, 3, 4, 5**

Grades 9-12:

- Origin and evolution of the earth system:
    - the sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early earth was very different from the planet we live on today; **1, 2, 3, 5**
    - geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods include using the known decay rates of radioactive isotopes present in rocks to measure the time since the rock was formed; **1**

Content Standard E: Science and Technology

Grades K-4:

- Understanding about science and technology
    - Science is one way of answering questions and explaining the natural world; **1, 2, 3, 4, 5**
    - people have always had problems and invented tools and techniques to solve them; **5**
    - scientists and engineers often work in teams with different individuals doing different things that contribute to the results;

  - women and men of all ages, backgrounds and groups engage in scientific and technological work;
  - tools help scientists make better observations, measurements, and equipment for investigations; **5**

Grades 5-8:

- Understandings about science and technology
  - scientific inquiry and technological design have similarities and differences;
  - many different people in different cultures have contributed to science and technology;
  - science and technology are reciprocal;
  - perfectly designed solutions do not exist;
  - technological designs have constraints;
  - technological solutions have intended benefits and unintended consequences;

Grades 9-12:

- Understandings about science and technology
  - scientists in different disciplines ask different questions, use different methods and accept different types of evidence, many investigations require contributions from different disciplines; **1, 2, 3, 4, 5**
  - science often advances with the introduction of new technologies; **5**
  - creativity, imagination and a good knowledge base are all required; **2, 3, 4, 5**
  - science and technology are pursued for different purposes, science tries to understand the world, technology tries to meet human needs;
  - technological knowledge is often not made public because of patents and the financial potential of the idea or invention;

Content Standard F: Science in Personal and Social Perspectives

Grades K-4:

- Changes in environments:

- environments are the space, conditions and factors that affect an individual's and a population's ability to survive and their quality of life; **2**

National Geography Standards: (see Unit Sections)

return to generalized geography standards

Element 1: The World in Spatial Terms

1) How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective; **3, 5**

2) How to use mental maps to organize information about people, places, and environments in a spatial context;

3) How to analyze the spatial organization of people, places, and environments on the earth's surface; **3, 5**

Element 2: Places and Regions

1) The physical and human characteristics of places;

2) That people create regions to interpret earth's complexity;

3) How culture and experience influence people's perceptions of places and regions;

Element 3: Physical Systems

1) The physical processes that shape the patterns of earth's surface;

2) The characteristics and spatial distribution of ecosystems on earth's surface;