MUSEUMS of WESTERN COLORADO EDUCATION

Paleontology
Museum Education Kit

Teacher Background Information

Paleontology

Topics included:
- » What is Paleontology?
- » What is a paleontologist?
- » What is a fossil?
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- » Extinction Events
- » Taxonomic Diversity

What is Paleontology?
Paleontology is the study of past life. There are a number of subdisciplines that make up paleontology. For example:
- » **Paleobotany** is the study of fossil plants
- » **Invertebrate Paleontology** is the study of fossil invertebrate animals such as molluscs or insects
- » **Vertebrate Paleontology** is the study of vertebrate animals including fish, amphibians, reptiles, birds, and mammals
- » **Ichnology** is the study of trace fossils
- » **Paleoecology** is the study of past ecosystems and climate
- » **Taphonomy** is the study of what happens to an organism from the time it dies until it is discovered.

In general, paleontology combines knowledge from disciplines such as geology, biology, and even computer science to understand the evolution and extinction of various forms of life from the time the Earth began and how those organisms and patterns of extinction relate to present-day.

Paleontology is often confused with archaeology by the general public. Archaeology is the study of human history and prehistory through the analysis of artifacts and human remains.

What is a paleontologist?
A paleontologist is a scientist who studies fossils. They research a variety of topics such as the relationships between extinct organisms and their living relatives. They collect and analyze both fossil and geologic data to reconstruct past ecosystems to understand present day environments. They study extinction events throughout the Earth's history and apply their conclusions to extinction in the modern world.

Paleontologists conduct their research in both field and lab environments. They can be found working in museums, universities, private industry, and for state and federal agencies.

What is a fossil?

Fossils are evidence of past plant and animal life. In order to be a fossil, the material must be at least 10,000 years old. Fossils can vary in size from small microorganisms, including single celled bacteria and insects, to large plants and animals such as trees and dinosaurs. The chart below shows examples of different types of fossils.

Plant Fossils	Animal Body Fossils	Trace Fossils
Pollen	Bones	Burrows
Seeds	Teeth	Tracks
Leaves	Tusks	Trails
Stems	Shells	Coprolites (fossil dung)
Wood	Mummified or Frozen remains	Bite Marks
Roots	Exoskeletons of invertebrates	
Flowers	Casts	
Cones	Molds	

What is a Dinosaur?

Dinosaurs are a diverse group of reptiles that first appeared in the Triassic period 230 million years ago and dominated the landscape until the end of the Cretaceous period. Many species of dinosaur went extinct 66 million years ago, but they do continue on today in the form of birds.

Dinosaurs have several distinguishing features. They all laid eggs, and with the exception of some birds today, they all lived on land. Dinosaurs had an upright stance with an open hip socket (acetabulum), instead of the sprawling posture seen in lizards and other reptiles. They are diapsids, meaning they had two holes (fenestrae) in the skull behind the eye socket to accommodate large jaw muscles. However, over time, the bony bridge separating the two holes was either partially or completely lost.

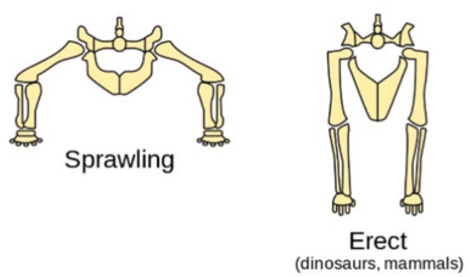


Figure 2 Sprawling vs Upright Stance

Adapted from an image by Fred the Oyster, via Wikimedia Commons, licensed under CC BY-SA 4.0

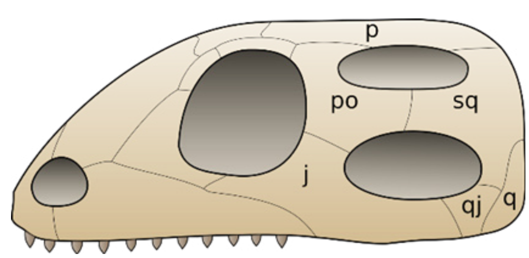


Figure 3 Diapsid Skull

Adapted from an image by Gagea, via Wikimedia Commons, licensed under CC BY-SA 3.0

There are two main branches of dinosaurs based on the structure of their pelvis:

The **Saurischia** (sawr-ISH-ee-uh) are the group of dinosaurs most closely related to modern birds. Early saurischian retained the hip structure of their ancestors, which is why they are referred to as "lizard hipped" dinosaurs. Saurischia includes theropods and sauropods.

The other group is the **Ornithischia** (or-nith-ISH-ee-uh) or "bird hipped" dinosaurs. This group is more closely related to Triceratops than birds. Note: "lizard hipped" and "bird hipped" are misnomers because birds evolved from Saurischia.

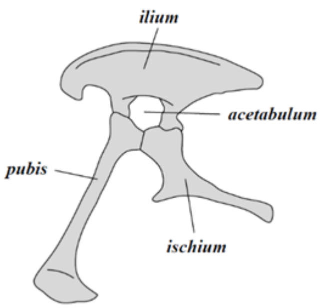


Figure 4 Saurischian Hip

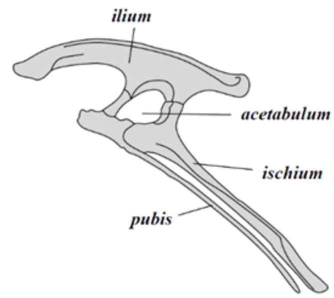


Figure 5 Ornithischian Hip

Collecting Fossils

Some students may want to know where they can collect fossils. The following are the rules regarding fossil collection:

Landowner	Type of Fossil	Can I collect fossils?
National Park Service	Plants, Invertebrates, Vertebrates	Permit required
National Conservation Areas: McInnis Canyon, Dominguez-Escalante & Gunnison Gorge	Plants, Invertebrates, Vertebrates	Permit required
State Parks	Plants, Invertebrates, Vertebrates	Permit Required
Bureau of Land Management (BLM)	Plants & Invertebrates	Yes, but restrictions apply
	Vertebrates	Permit Required
US Forest Service	Plants & Invertebrates	Yes, but restrictions apply
	Vertebrates	Permit required
Private	Plants, Invertebrates, Vertebrates	Landowner permission required

Why can’t I collect vertebrate fossils?

Vertebrate fossils are rare compared to plant and invertebrate fossils. Scientists can learn a lot by finding the fossil in its original context. When someone removes a fossil, that context is lost along with all of the important scientific information.

Why can’t I collect fossils anywhere I want?

The Paleontological Resources Preservation Act (PRPA) is the United States law preserving paleontological resources on federal land. This act protects scientifically significant fossils on federal land against vandals and the abuse of fossils at the expense of scientific discovery.

What do you do when you find a fossil you don’t have permission to collect?

Take a picture and GPS coordinates if possible and give that information to a Park or BLM Ranger or a paleontologist at a local museum.

Geologic Time Scale

Much has happened during the Earth’s 4.56-billion-year history. The geologic time scale is a way to organize the Earth’s past into different units based on events that have taken place. This is done by relating the stratigraphy (rock layers) to radiometric ages (see below).

Absolute vs. Relative Dating

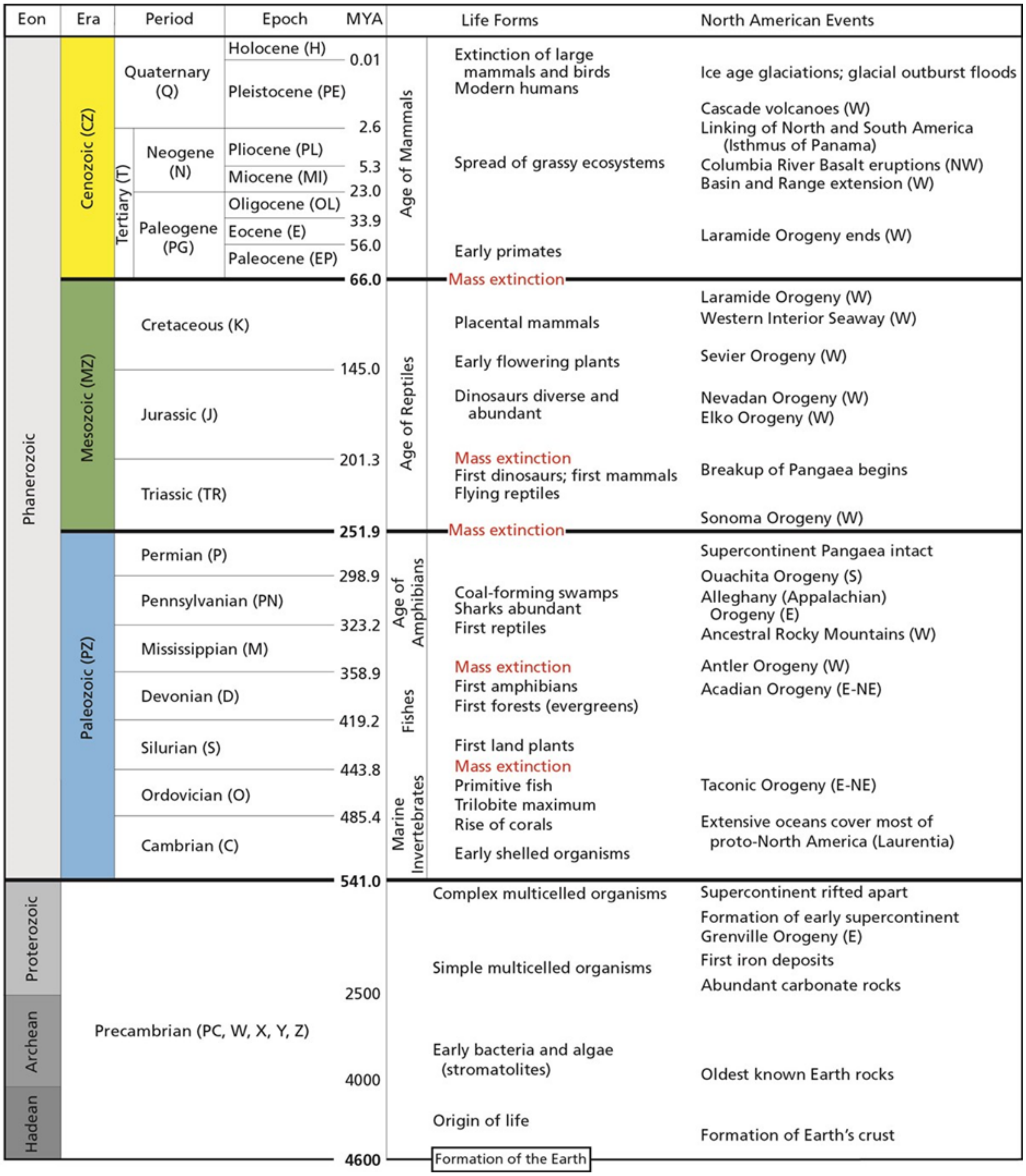
The numerical (absolute) ages for certain rock layers obtained by using radiometric dating—a method that looks at the proportions of certain radioactive isotopes remaining in a sample. Samples can be either rocks or the fossils themselves. Radiometric dating is a reliable method because the unstable radioactive elements have a known half-life, which is the amount of time it takes for half of the radioactive isotopes to decay. During radioactive decay, the original isotope, called the parent isotope spontaneously converts to a new isotope called the daughter. Knowing the half-life of a radioactive element and the proportion of parent isotopes left in a sample can give us the age of a rock or fossil.

Carbon-14 is an example that can be used on fossil material, but not the rocks themselves. Radioactive carbon has a half-life of 5,730 years. As a result, it can only be used on relatively young fossils. By the time 60,000 years have passed there will be not enough radioactive carbon left to date a sample. On the other hand, elements such as uranium, argon, and potassium have long half-lives that can be used to determine the age of very old rock units.

However, not every rock layer has radioactive isotopes that can be measured. In this case, scientists rely on what is known as relative dating. Relative dating uses geologic principles to determine the order of events, but not the ages of different rock layers.

Key Events in the Earth’s History

The chart below is a geologic time scale that highlights major events that have happened in the Earth’s past. A common abbreviation when referring to geologic time is MYA, which stands for: million years ago. The majority of the fossils on display at Dinosaur Journey are from the Mesozoic Era, with a small section on the Cenozoic Era. Another note about the time scale below, the term orogeny refers to a mountain building event.



NPS Geologic Resources Inventory, 2018

Evolution

Evolution happens when there are a variety of traits in a population, such as hair/fur color, height, or feathers. These traits can be inherited from one generation to the next. Traits that are contained within DNA that can be passed down from one generation to the next are genetic traits. Some genetic traits can be harmful to an individual, while other traits can help individuals survive and reproduce. The more offspring produced by an individual, the more of that individual's genetic traits will survive in a population. This process where individuals that are best suited to their environment survive and pass down their genetic traits to future generations is called natural selection. Meanwhile individuals that are less well adapted to their environment might not survive or be able to produce as many offspring, which means fewer of their genetic traits are present in future generations.

When an ancestral population is divided by a physical (such as a mountain range or body of water) or behavioral barrier, the subpopulations can diverge enough genetically that a new species arises when the groups are no longer able to interbreed. We cannot tell which organisms were able to interbreed by looking at the fossil record, so instead we look at the physical characteristics (morphology) of the fossil organisms. We can infer that organisms that have significant morphological differences represent different species.

Evolution is well supported via experiments and observations and widely accepted among the scientific community. As a scientific theory, it can be repeatedly tested and verified using the scientific method. Like all scientific theories, evolution has withstood rigorous scrutiny and can predict the behavior of the natural world.

Extinction Events

Approximately 99.9% of all life that ever lived on Earth is now extinct. However, extinction rates have not been constant throughout geologic time. Depending on the criteria used, scientists estimate there have been anywhere from five to twenty extinction events in the Earth's history. When determining whether or not an extinction event has occurred, scientists often look to the marine fossil record because marine fossils have better preservation and a wider stratigraphic range compared to the terrestrial record. During an extinction event, there is a rapid, widespread decrease in biodiversity on the planet. Although extinction events eliminate a large number of species on the planet, they also make way for new and different species to arise.

In 1982, Jack Sepkoski and David M. Raup published a landmark paper where they identified five mass extinctions. These were originally thought to be outliers; however, improved statistical tests have revealed that animal life on Earth has experienced at least five major and many minor extinction events. The "Big 5" extinction events are as follows:

1. **End Ordovician Extinction:** 443 million years ago. This is a series of two extinctions that occurred a million years apart and eliminated approximately 85% of marine life at the time. It is believed that climate change in the form of a major ice age played a role in these extinctions.

2. **Late Devonian Extinction:** 385-365 million years ago. Near the end of the Devonian Period, there were a series of three extinction events, each separated by 10 million years. Only the event occurring at 375 million years ago is large enough to be considered part of the Big 5. This extinction was most prominent in tropical seas where many corals, sponges, brachiopods, and trilobite genera went extinct. It is believed that a cooling climate played a role in this extinction event.

3. **End Permian Extinction:** 252 million years ago. This was the largest extinction event in the history of life. Up to 75% of marine genera were lost along with up to 70% of terrestrial vertebrates. Warming of the Earth's climate caused by massive volcanism emitting carbon dioxide into the atmosphere and associated changes to oceans were the most likely causes of the extinction.

4. **End Triassic Extinction:** 201 million years ago. Like the End-Permian extinction, climate change brought on by global warming is believed to be responsible for the major drop in biodiversity that saw extinctions both in the sea and on land. This event paved the way for dinosaurs to dominate the landscape

5. **End Cretaceous Extinction:** 66 million years ago. This is the extinction event that wiped out all dinosaurs except birds. This event also wiped out flying and swimming reptiles, and important marine invertebrates. There are multiple lines of evidence to suggest that an asteroid as big as 6 miles across struck the planet near what is today the Yucatan Peninsula in Mexico. This impact would have created an enormous

cloud of dust and debris that would have limited sunlight and thus disrupt the food chain. Also occurring at the time was increased volcanism in present-day India that may have also altered the climate.

Why do paleontologists count genera instead of species?

From the Sam Noble Museum

It isn't easy for biologists to measure the number of extinctions that are happening in the modern world. We need a good estimate of the number of species that are currently alive in order to determine how many have become extinct in the future. We have a good idea of the number of species of animals and plants in developed countries like the United States, and historical records show that there have already been extinctions over the last 250 years. In more remote places, like the Amazon rainforests of South America, new species of animals (e.g., insects) are still being found. In these parts of the world, our estimates of extinction will be less accurate. Some species may literally go extinct before biologists are able to discover them. Rare species that have been discovered may seem to have become extinct because they are difficult to find again. Biologists have developed various mathematical methods to deal with these sampling problems.

Taxonomic Diversity

It is even more difficult to study extinction in the remote past. We can never find fossils of every species that has ever lived. Many will not be preserved as fossils because they don't have a hard skeleton of shell and bone. Even if an individual animal has a hard shell, it will not be preserved if it is eaten by a predator, or if its shell is broken apart by waves after it dies. Common species are more likely to be discovered than rare species.

Paleontologists have a better chance of making an accurate estimate of what is called taxonomic diversity. Species are classified into a set of progressively larger groups called taxa (s. taxon). For example, several closely related species may be combined into a genus (pl. genera). A number of related genera form a family, and a set of related families are combined into a superfamily; and so on. To count a genus as having existed at a time in the past, you need find just one specimen of only one of the species that belong to that genus. We have a better chance of getting an accurate count of diversity if we consider taxa instead of species.

There are other sampling issues that must be accounted for in estimating taxonomic diversity. For example, the more specimens you count, the more taxa you find (also a problem when counting modern animals or plants). If there are large differences in counts between time periods, diversity will appear to change as a result of these sampling differences. Paleontologists use a variety of statistical methods to overcome these sorts of sampling problems.

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Lesson 1

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Lesson 3

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