

“Therizinosaur-Mystery of the Sickle-Claw Dinosaur”

Arizona Museum of Natural History

Educator Resource Guide



Illustration Courtesy of Victor Leshyk

GOALS FOR VISIT**G**

To help understand the history of life on earth through the study of dinosaurs.

Students Will Understand That:**U****Essential Questions****Q**

- The North American continent during the Cretaceous Period was very different from what we know today.
- Much of the North American continent was under water during the Cretaceous Period.
- There was a huge diversity of life in the southwestern part of the United States during the Cretaceous Period.

- What was the Western Interior Seaway?
- Did dinosaurs have feathers?
- What did the *Therizinosuar* eat?
- What is the mystery of the *Therizinosar graffami*?

Students Will Know:**K****Vocabulary Words****A**

- How scientists use scientific inquiry to study fossils.
- The kind of food a dinosaur ate can be determined by the type of teeth it had.
- How the *Therizinosaur graffami* was discovered.

Carnivore
 Cretaceous Period
 Geologic Time Scale
 Herbivore
 Mesozoic Era
 Omnivore
 Paleontologist
 Paleontology
 Plate Tectonics

Learning Plan**L**

This packet was written as a companion to our Dinosaur Educator Resource Guide. Please refer to that packet for relevant State Standards and activities.

State Standards Met in Packet**SS**

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Looking across the mid-section of the continental United States it is hard to believe much of this vast expanse of land was once submerged beneath a shallow ocean. The immense Western Interior Seaway, also called the Cretaceous Seaway, Niobraran Sea or the North American Inland Sea, was one of the largest continental seas of all time.

These waters teemed with giant predatory fish and monstrous marine reptiles. Plesiosaurs, mosasaurs, and a variety of sharks hunted the waters of this large inland sea. These formidable carnivores would have preyed on the numerous smaller fish and invertebrates that shared their watery domain, as well as each other. Ammonites and nautiloids probably moved with the currents, sinking to the deeper waters during the day and coming to the surface under the protective cover of night. Paleontologists suggest the giant size of these creatures was an adaptation for life in the murky bottom waters, where a correspondingly large gill area would have allowed the animals to cope with anoxic (lack of oxygen) conditions. There was a great diversity of life in these waters and our knowledge of this fauna is great, but our knowledge of the land animals of this region is less complete. The shale formations of this seaway have given us a fossil record of the abundant marine life of this inland sea.

These aquatic reptiles lived during the age of dinosaurs, but are NOT dinosaurs themselves. The dinosaurs were a specific group of land dwelling animals during the Mesozoic Era between approximately 250 and 65 million years before present. Dinosaurs, with the exception of birds, did not fly nor could they live in the water.

The Western Interior Seaway is known for its skeletons of prehistoric sea monsters. Numerous North American fossil sites owe their existence to this waterway. The shallowness of the sea, the relatively flat and soft, oxygen-depleted mud bottom helped with the processes of fossilization.

The paleontologists of the Museum of Northern Arizona excavated the area just north of the Arizona border in southern Utah near Lake Powell for several years. Among their finds were several plesiosaurs, sea turtles, fish and sharks. In 2000 a local resident, Merle Graffam, found a toe bone too large to be from a

plesiosaur. It was obviously a dinosaur bone. But what was a dinosaur, a land dwelling creature, doing so far from the shore among the fossils of marine life?

As the excavation continued the crew was astonished to realize they had uncovered the skeleton of a sickle-claw dinosaur, until then known only in Asia and only from partial skeletons. This exhibit, “Therizinosaur, Mystery of the Sickle-Claw Dinosaur” is the story of that remarkable discovery and how this land dwelling dinosaur came to be found on the bottom of the sea more than sixty miles from the shore.

This inland sea split the continent in half and covered much of North America during the early to mid Cretaceous Period from approximately 130 to 70 million years before present (mybp). At its peak around 90 million years ago, this seaway stretched from Utah in the west to the Western Appalachians in the east, a distance of over 600 miles. The northeastern tip of Arizona was underwater at times. The seaway also reached from the Arctic to the Gulf of Mexico and covered much of the southeastern United States including every state adjacent to the modern day Gulf of Mexico.



Photo courtesy of abosluteastronomy.com

The Western Interior Seaway was created during one of the greatest transgression events (sea level rise) of all time. This transgression event may have been caused by sea floor spreading taking place in the Atlantic Ocean. There was so much new rock created on the sea floor it lowered the overall capacity of the Atlantic basin and raised worldwide sea levels for millions of years.

Over millions of years, collisions of the Pacific and the North American Tectonic plates had caused the ancestral Rocky Mountains to form in the western part of North America. With the high sea levels from the transgression event during the Cretaceous, cold water from the Arctic and warm water from the Gulf of Mexico flowed into the mid portion of the North American continent

The Western Interior Seaway grew and receded over the course of the Cretaceous Period, forming shifting delta systems along its low-lying coasts. At its deepest the seaway was only about a half mile deep, relatively shallow for a sea.

Carbonate deposition indicates the Seaway was warm and tropical. Although there is no contemporary body of water to compare to the Western Interior Seaway, wherever warm and cold waters mix in the modern world, including in deltas and estuaries, there is an abundance of nutrients to support a rich planktonic base.

By the end of the Cretaceous Period the continuous uplifting of mountain building had hoisted the sandbanks and the muddy brackish lagoons. At the same time the lower lying basins between these newly elevated banks gradually disappeared. The seaway divided across the Dakotas and retreated south towards the Gulf of Mexico. This regressive phase of the Western Interior Seaway is also called the Pierre Seaway.

Nothronychus graffami

Therizinosaur

Therizinosaur means “sickle-claw dinosaur”, a reference to the creature’s most striking features, the three enormous claws on each front foot. So far, fossils have been found in Early Cretaceous through Late Cretaceous deposits in Mongolia, China and North America. There are twenty- eight known species of therizinosaurs.

The therizinosaur in this exhibit, *Nothronychus graffami*, exhibit is from the genus *Nothronychus*, which means “slothful claw”.

Therizinosaur is a general name that includes all of the species in the Family Therizinosauridae. The major characteristics of this family include the enormous claws on the front feet, hip sockets set far apart with broad expansive hipbones that flare sideways, four toes on the rear feet and a toothless “beak” with dull teeth designed for chopping.

Therizinosaurs are theropods, a group that includes all carnivorous dinosaurs. Theropod dinosaurs were bipedal, at least some had feathers, and most shared predatory characteristics such as sharp teeth, strong jaws, three toes and the ability to move quickly.

Coelophysis, *Allosaurus*, *Velociraptor* and *Tyrannosaurus* were all theropods. Birds, which are technically theropods, evolved from this order.

It is hypothesized the therizinosaurs evolved from carnivores to herbivores. They show the beginnings of features we associate with plant eaters, including a change in the size of teeth from large meat-cutting to smaller leaf-shredding teeth, the expansion of the gut to a

size needed to ferment plants and the early stages of changes in the legs to carry a bulky body.

FAST FACTS:

- *Nothronychus graffami* lived 93 million years ago.
- An adult therizinosaur stood about 12 feet tall, was about 15 feet long and weighed between ½ ton to ton.
- The claws, with sheath, measured about 15 inches long.
- Believed to have had feathers, but these were not used for flight. The feathers most likely helped to regulate body temperature and provided visual displays for mating and competition.



Photo courtesy of Rob Gaston, 2008

Ammonite Fossil

Ammonites were early mollusks that appeared in the early Devonian and survived through the Cretaceous Period when they became extinct. Ranging in size from about ½” to 7 feet, depending upon the species, they had no vertebrae, but were protected by a hard shell made of calcium. Ammonite shells could be spiraled, curled upon itself or straight. The name comes from “horns of Ammon”, a Greek god represented by a ram’s horn.

Found worldwide, Ammonites lived in marine waters, likely preferring warm shallow waters. Fast moving predators, they ate a variety of prey, including carrion, crabs and fish. Ammonites moved themselves by jet propulsion, expelling water through a funnel-like opening to propel themselves in the opposite direction. This is similar to today’s octopus, squid, cuttlefish, and nautilus. They likely caught their prey by silently stalking it, then rapidly extending their tentacles to grasp the target. Once caught, the prey was eaten by the powerful jaws located at the base of the tentacles, between eyes. Ammonites, in turn, may have been prey for mosasaurs and bony fishes.

Ammonites are very similar to the modern chambered nautilus.



Photo courtesy of Arizona Museum of Natural History

Mosasaur

Now extinct, Mosasaurs were marine reptiles that lived in the warm shallow seas prevalent during the Late Cretaceous Period. Believed to have been related to monitor lizards such as the Komodo Dragon, new evidence suggests they may be more closely related to snakes.

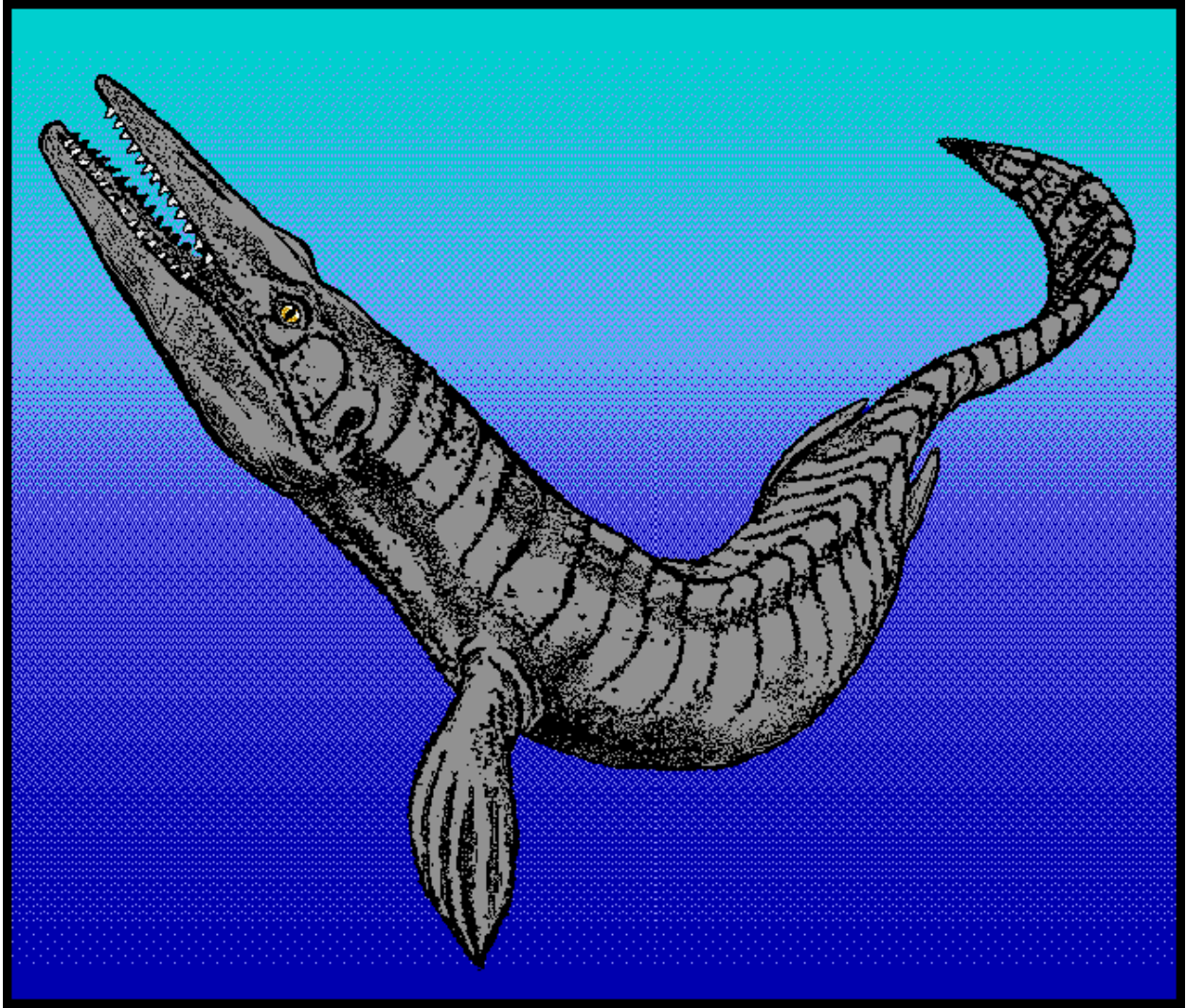
Mosasaurs have been found all over the world and were among the dominant carnivores during their time, feeding on fish, squid, ammonites, turtles, small plesiosaurs and even other mosasaurs. These creatures had a double hinged and flexible jaw and pterygoid teeth, allowing them to swallow their prey whole.

The discovery of the first Mosasaur fossil in the late 1700s near Maastricht, Holland predated the discovery of dinosaurs by more than fifty years.

These creatures were well adapted to living in the warmer seas during the Late Cretaceous Period. Air breathers and powerful swimmers, they had a body shape similar to that of modern day monitor lizards but more elongated and streamlined for swimming. Mosasaurs had broad tails that supplied the power for locomotion, similar to that used by conger eels and sea snakes today.

Mosasaurs gave live birth to their young and may have even provided some form of parental protection. There is evidence that groups of all ages and sizes lived together.

Most Mosasaurs ranged in size from about twelve to twenty-four feet in length. One genus of Mosasaurs living in the Western Interior Sea, *Tylosaurus*, reached up to thirty to forty feet in length.



Courtesy of www.oceansofkansa.com

Plesiosaurs

Plesiosaurs, whose name means “near lizard” were marine reptiles that lived during the Mesozoic Era. Their fossils have been found all over the world, including North America, in Cretaceous and Jurassic sediment.

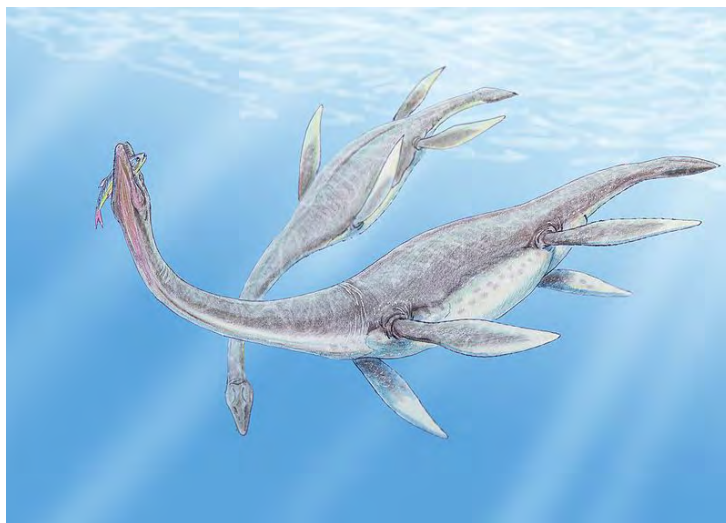
They ranged in size from eight feet to forty-six feet long, had four flippers, sharp teeth in strong jaws and short pointed tails. Plesiosaurs lived in the open oceans and breathed air.

The common name plesiosaur refers to both the long necked elasmosaurs and the short necked group called polycotyloid. It also included the larger taxonomic rank of Plesiosauria, which includes the pliosaurs. Although the plesiosaurs lived at the same time as dinosaurs, these were sea reptiles, not dinosaurs.

Plesiosaurs were carnivorous and ate fish and other swimming animals. They lived in the large bodies of water and were air-breathing animals. Plesiosaurs were probably slow swimmers, cruising slowly just below the surface. They swam using their four paddle-like flippers in a manner similar to that of modern turtles. This swimming style may have provided great maneuverability, so they could swiftly turn their bodies to catch prey.

Some plesiosaurs fossils were found with small stones in their stomachs. These may have been used to help grind up their food or perhaps as ballast to help them dive.

The plesiosaur in the Cretaceous Sea diorama is a polycotyloid. The plesiobot is a long necked elasmosaur.



Coelurosaur

This name, which means “hollow-tailed reptiles” applies to the large group of meat eating dinosaurs that includes allosaurs, tyrannosaurs and oviraptors. The most advanced members of this group are related to birds and may have had feathers.

This dinosaur is a new species and is unnamed so far. Before receiving a scientific name, a detailed study is undertaken to determine how it is different from other dinosaurs as well as how it may be related. “Little Tooth” is its unofficial nickname.

The Zuni Basin Coelurosaur was found in the Cretaceous Period rocks of the Moreno Hill Formation near the Arizona and New Mexico border during excavations sponsored by the Arizona Museum of Natural History. The *Zuniceratops* was found in this formation, along with fossil turtles, fish, crocodiles and lizards.

This reconstructed cast of the skeleton is a composite of two partial fossil skeletons found in rocks that were once forested swamps, lakes and streams ninety million years ago.



Photo courtesy of Arizona Museum of Natural History



www.bbc.co.uk

Zuniceratops Christopheri

This dinosaur, whose name means “Zuni horned face”, after the Zuni nation of North American Indians was found in 1996 by 8 year old Christopher Wolfe. Christopher is the son of Douglas Wolfe, a paleontologist then affiliated with the museum.

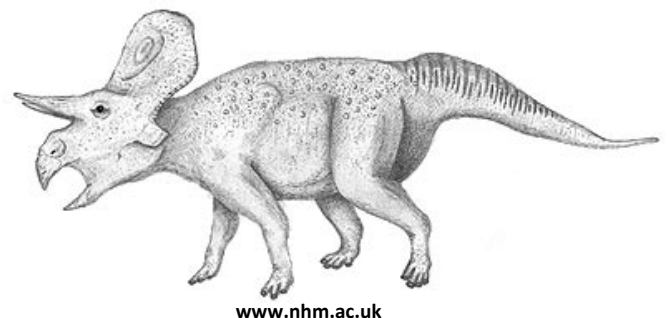
This frilled plant eater lived in the Cretaceous Period, around 90 million years ago in what is now New Mexico and is the earliest known ceratopsian to have brow horns. This was about ten millions years before the more familiar *Triceratops*.

It is the oldest known ceratopsian from North America and represents an evolutionary transition between earlier ceratopsians such as the Asian *Protoceratops* and the later, larger North American ceratopsians that had large horns and frills.

Zuniceratops had a beak like snout with small horns and teeth that could slice up plant food. It was 10 to 12 feet long, about 3 feet high at the hips and weighed perhaps as much as 400 pounds.



Image courtesy of Arizona Museum of Natural History



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Pteranodon

Pteranodon, whose name means “winged and toothless” was a member of the order *Pterosauria*.

It lived during the Late Cretaceous period, about 85 to 75 million years ago. Its fossils have been found in North America and Europe.

Although the *Pteranodon* lived during the age of dinosaurs and was a reptile, it WAS NOT a dinosaur.

A *Pteranodon* had a wingspan of perhaps 25 feet, longer than that of any known bird. The animal probably weighed up to about 25 pounds, although it looked heavier than it actually was because the bones were large but hollow, reducing the weight of the creature. Many had large crests on their head and a very short tail.

It was a carnivore and its diet probably consisted mainly of fish.

It may have been a glider rather than a true flyer although some paleontologists believe it may have been a very good flyer.

It was probably endothermic (warm blooded) and may have been covered in fur-like filaments.



Shale

Shale rock is the most common type of sedimentary rock. It is mainly formed from clay, with tiny fragments of other minerals, especially quartz and calcite, compacted together by pressure.

Shale is Fissile, or capable of being split in the direction of the grain or along natural planes of cleavage, often breaking into thin layers.

Shale is typically deposited in very slow moving water and is often found in lakes, lagoon, river deltas, on floodplains and offshore from beach sands. It can also be deposited on the continental shelf.

When shale is subjected to greater heat and pressure it becomes the metamorphic rock slate, and with even more metamorphism it becomes phyllite then schist.

Body fossils, animal tracks and burrows can be preserved on shale bedding surfaces. The Therizinosaur in this exhibit, *Nothronychus graffami* was found in this type of rock.



Courtesy of the State of NewSouth Wales Department of Education
and Training



These pieces of shale are from the *Nothronychus*
graffami dig site.

Types of Feathers

A bird has a variety of different types of feather. Each has its own function.

Contour Feathers These are the largest feathers on the bird. They give the bird its shape and color. There are three types of contour feathers, **remige**, **retrice**, and **body**. Feathers of this type are also called **pennaceous**.

Remige Wing or flight feathers, these are asymmetrical, the vane is much smaller on one side than the other. This is because the pressures on the edge (front facing part of feather) are far greater than those on the trailing edge. If the leading vane was as large as the trailing edge it would soon become ragged and not work properly.

Retrice Tail feathers, are much more symmetrical.



Body Contour Feathers These feathers give the bird its characteristic smooth round shape. They also give the bird its visual coloring and provide a first level of defense against sunlight, wind, rain and physical objects.



Down Feathers These are the next most important feathers on a bird. They are smaller and lack the barbules and hooklets, so they do not “zip” together and do not look as neat as contour feathers. Rather, they are soft and fluffy and are used for insulation. The side branches are longer than the rachis on down feathers. Feathers without barbs are also called **plumulaceous** feathers.

Down Feather



Semiplume These are half-way between a contour feather and a down feather. These are located between the contour feathers and help supply insulation as well as a certain amount of form.

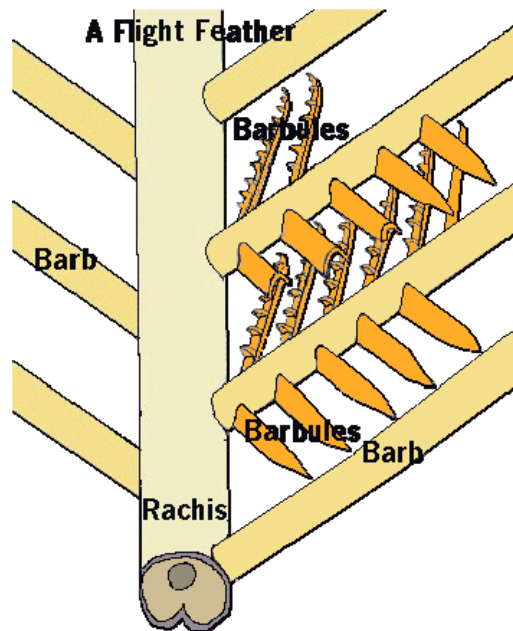
Filoplume These feathers have only a very few barbs at their tips and are believed to have a sensory function, helping birds keep their feathers in order.

Bristles They have practically no barbs at all and are stiff. They grow around the eyes and mouths of some birds and are protective in function.



Parts of a Feather

- Rachis** central hollow support shaft
Barbs side branches
Barbules hooklets to keep barbs together, the gripping effect of any one set of barbule hooklets is not great, but the combined effect is enough to keep the barbs "hooked" together
Calamus or quill, the base of the feather
Inferior Umbilicus entrance used by blood vessels to carry nutrients to the growing feather.
Vane the overall presence of the barbs and barbules



Functions of a Feather

Feathers perform many functions on a bird. These would include:

Insulation

Protection from Ultra Violet light

Allow for flight

Control what a bird looks like

Supplies coloration for camouflage and for secondary sexual characteristics and displays



Down feathers for insulation



Contour feathers cover the body

Willow Ptarmigan

Winter plumage



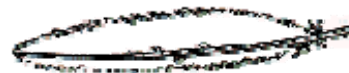
Summer plumage



Feathers used for camouflage



Secondary Sexual Characteristic

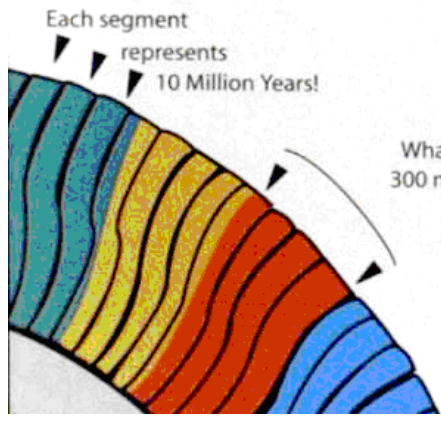
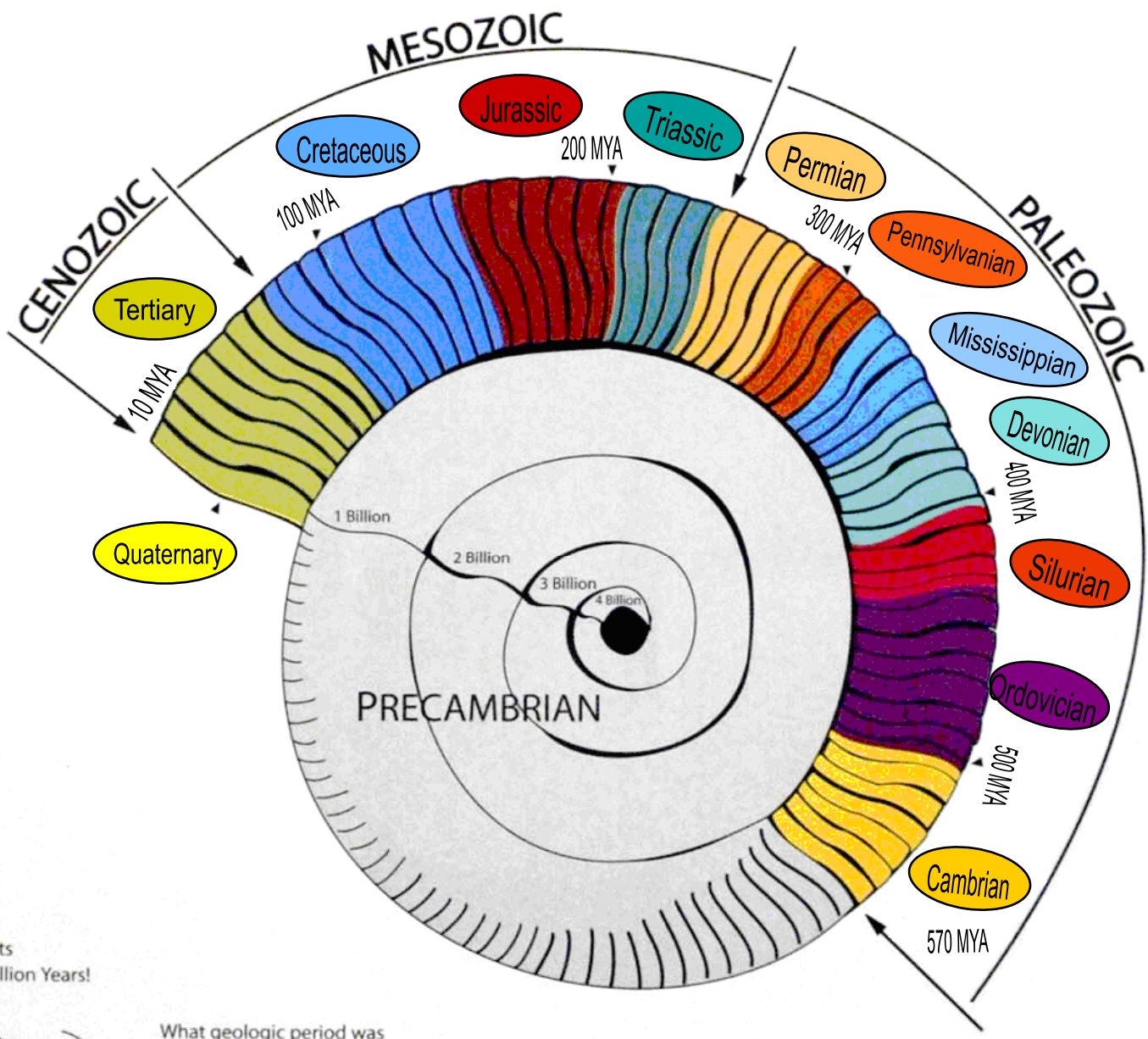


Flight or wing feather

Feathered Fun Facts

- Feathers are unique to birds.
- Every bird has feathers and everything with feathers is a bird.
- Feathers evolved from reptilian scales and birds still possess scales on the lower parts of their feet.
- Feathers grow quickly and then are sealed off at the base.
- A fully developed feather is dead-matter (like finger nails and hair), but there are muscles attached to the base of each feather to allow that individual feather to move.
- Feathers are made of **Keratin**, a protein also used to produce nail, hair, beaks, claws, and hooves.
- Feathers do not last forever, they can become worn and battered.
- Feathers are replaced one or twice a year, depending upon the species. This is called **Moult** or **Moulting**.
- In primitive birds, the feathers appear to grow at random all over the body, but in most orders the feathers appear in well-defined patterns of rows or tracts called **pterylae**.
- The number of feathers a bird has depends very much on its size and where and how it lives. In general, a bird has one third of its feathers on its head.

Telling Geologic Time



Vocabulary Words

Carnivore: Any meat-eating animal.

Cretaceous period: The Cretaceous Period was the third and last geological time-period during the Mesozoic Era. The name comes from type of rock, known as chalk, deposited during this time. The Latin name for chalk is *creta*, thus the name Cretaceous. The Cretaceous Period is divided into two divisions. The Early Cretaceous (also called the Lower Cretaceous) was from approximately 144 to 89 million years ago and the Late Cretaceous (or Upper Cretaceous) lasted from approximately 89 to 65 million years ago.

Geologic Time Scale: The time scale is a way to put the long history of the Earth into perspective. There are four Eras, the Pre Cambrian from 4.6 billion years ago to 600 million years ago, the Paleozoic from 250 million years ago to 144 million years ago, the Mesozoic from 144 million years ago to 65 million years ago and the Cenozoic from 65 million years ago to 2 million years ago.

Herbivore: Any plant-eating animal.

Mesozoic era: The geological time-period often referred to as the age of the dinosaurs. This period lasted from approximately 250 million years ago to 65 million years ago. It is divided into three periods, the Triassic, the Jurassic and the Cretaceous.

Paleontologist: The scientist who specializes in paleontology.

Paleontology: The study of ancient animal or plant life. It does not include human life.

Plate Tectonics: The shell of the Earth is made up of nine large plates and about a dozen smaller ones. The study of these plates help explain continental drift, seafloor spreading, volcanoes and the formation of mountains.