

COLORADO CANYONS ASSOCIATION

FOSTERING COMMUNITY STEWARDSHIP OF OUR NATIONAL CONSERVATION LANDS

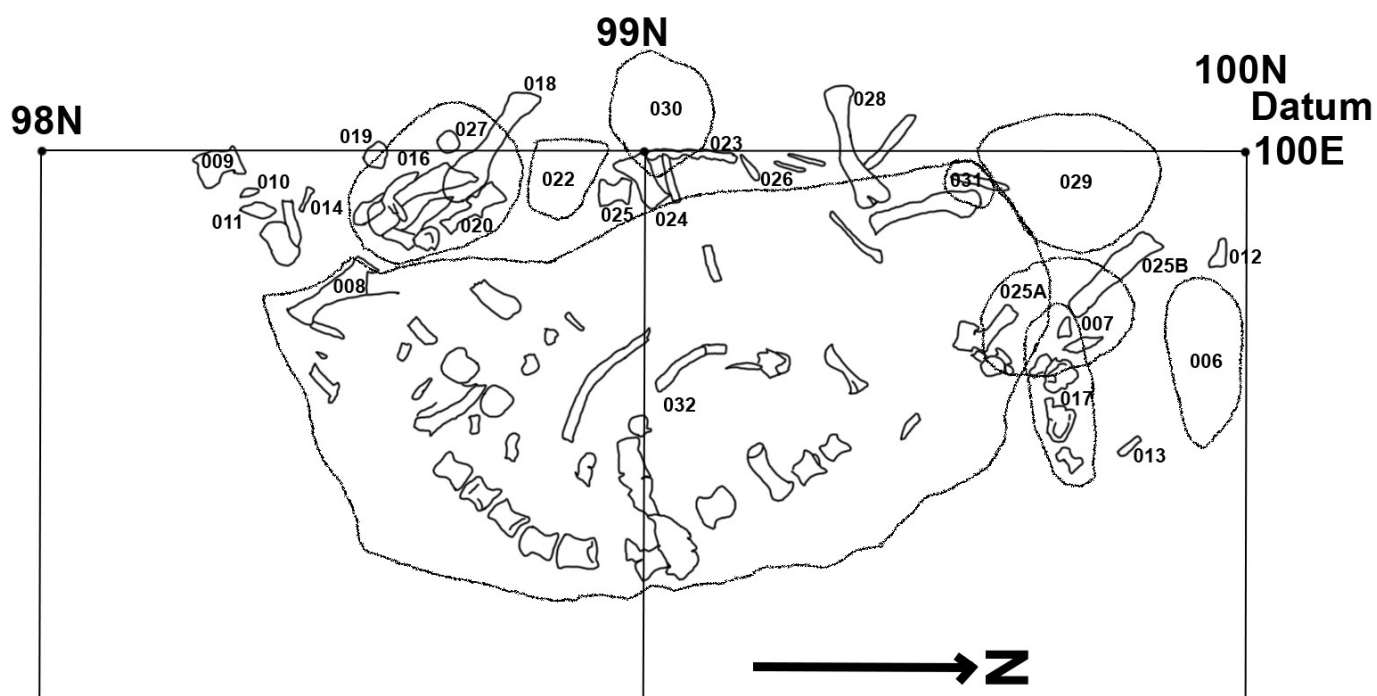
Paleontology Education Kits

Using kits on the land and in the classroom



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About the Kit

Colorado Canyons Association, in cooperation with the Bureau of Land Management, the Museums of Western Colorado, and the National Environmental Education Fund, have produced a series of five portable paleontology education kits. These kits allow students to experience both the latest science information about western Colorado as well as feel, hands-on, professional museum-quality replicas of the fossils that have been found in western Colorado. We are proud to present these materials and know that your students will enjoy using them to learn, grow, and understand more about the fossils of our National Conservation Areas.



The Morrison Formation

Intro to the Morrison Formation

The Morrison Formation is a sequence of rock units deposited by rivers, lakes, dunes, and deltas during the Late Jurassic Period (~156-146 million years ago).

Three members (or sub-units) of the formation are recognized on a broad geographic scale.

- Brushy Basin Member (youngest)
- Salt Wash Member
- Tidwell Member (oldest)

The Mygatt-Moore Quarry is located in the Brushy Basin Member and has been dated to approximately 152 million years old.

Morrison Formation

Deposited over a period of ten million years. This deposition occurred north-south from New Mexico to Canada and east-west from Utah to Nebraska.

In the Jurassic, North America was ~400 miles further south than today. To put that in perspective, if Chicago was 400 miles further south today, it would be roughly the same latitude as Tulsa, Oklahoma.

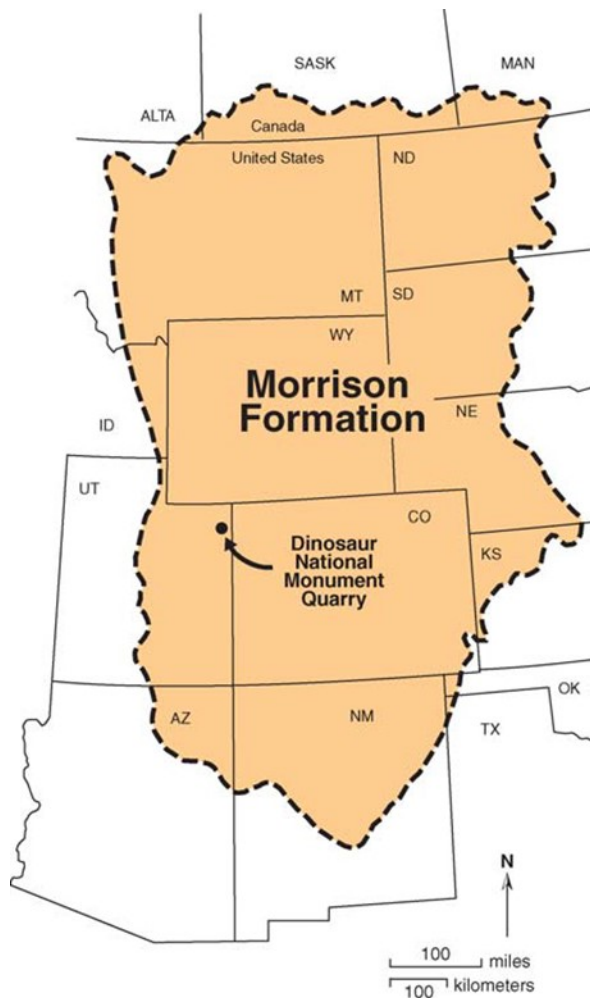
During Morrison times, Rivers ran from the west & south to east & north through



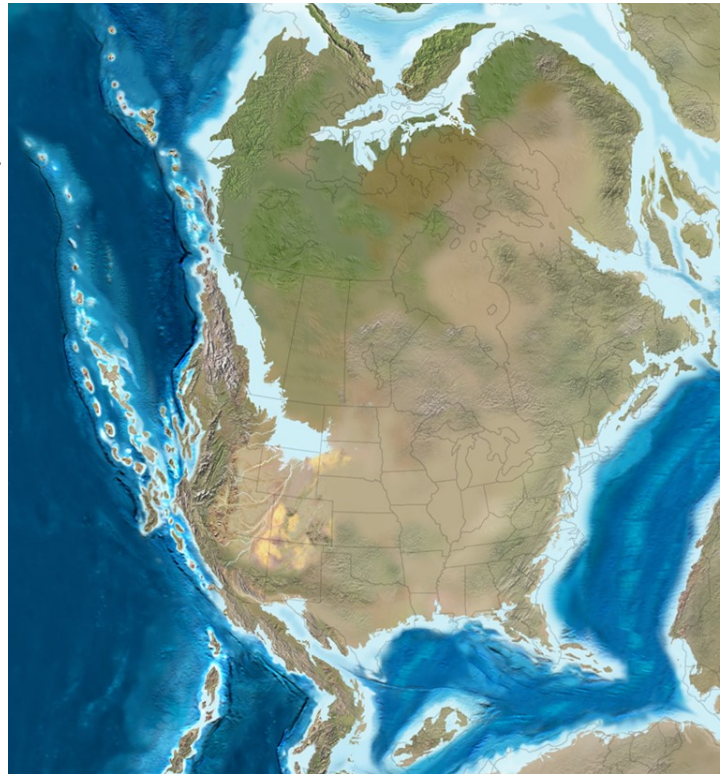
The Morrison Formation

low, flat terrain . Rivers eventually drained into an inland sea to the north.

Today the Morrison Formation is exposed over an area spanning 600,000 square miles in western North America. Most of the famous dinosaur sites are in the Brushy Basin Member. Dinosaurs are known from the Morrison Formation in all states where it is exposed.



Exposures of the Morrison Formation overlaid onto the western portion of North America. From Hoesch & Austin (2004)



North America during the Late Jurassic Period, when the Morrison Formation was being deposited.



Typical exposure of the Brushy Basin Member of the Morrison Formation. Photo by Anky-man

The Mygatt-Moore Quarry

The History of the Mygatt-Moore Quarry

The quarry was first discovered in 1981 by two local couples (Peter and Marilyn Mygatt and John “JD” and Vanetta Moore) out rockhounding in Rabbit Valley. Legend has it that one of the group sat down on a large boulder to take a break. When the group joined them, everyone realized that they were sitting on enormous **sauropod** vertebrae!

The find was reported to the local museum, then called Dinosaur Valley, and the Bureau of Land Management. Since then, professional crews have been excavating the fossils at Mygatt-Moore.

Paleontology of the Mygatt-Moore Quarry

The Morrison Formation was deposited by fresh water rivers, lakes, and deltas, and the fossils found in it are typically animals that lived in, or around those habitats . So what animals are typically found at the Mygatt-Moore Quarry?



Recent excavations in the Mygatt-Moore Quarry



A plaster jacket protects bones while they are still in the ground at the quarry



A plaster jacket once removed from the quarry

Allosaurus

Allosaurus is the most famous and most common meat-eating dinosaur from the Morrison Formation. Originally named for scrappy remains from the Front Range, *Allosaurus* became widely known as one of the best-represented theropod dinosaurs after a huge concentration of their remains were discovered in central Utah. The discovery and ongoing excavation of the Cleveland-Lloyd Quarry has allowed paleontologists to understand *Allosaurus* better than most any other carnivorous dinosaur known to date! In addition to finds here in the American West, *Allosaurus* is known from fossils found in Portugal and possibly in Africa. New studies have shown how *Allosaurus* was able to use its sharp teeth and hatchet-like jaws to dispatch its prey. A living *Allosaurus* would have been a terrifying sight to behold!

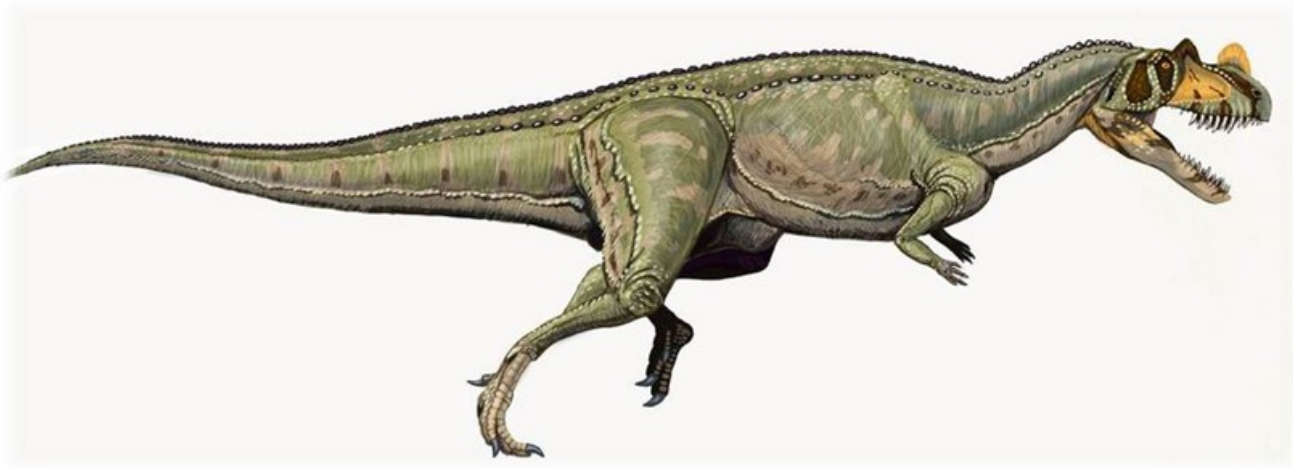


© SDNHM



Illustration by Brian Engh

Ceratosaurus



By DiBgd - CC BY 2.5

Ceratosaurus is a medium-sized carnivore from the Late Jurassic MMQ. This life reconstruction of *Ceratosaurus* accentuates the large nasal horn. One species of *Ceratosaurus*, *C. magnicornis*, has only been found in the Grand Valley and is named for its large, flat nose horn. *Magni* = large, *cornis* = horn/blade. The small arms and fingers of *Ceratosaurus* have led some scientists to speculate that they were not used in capturing its food.

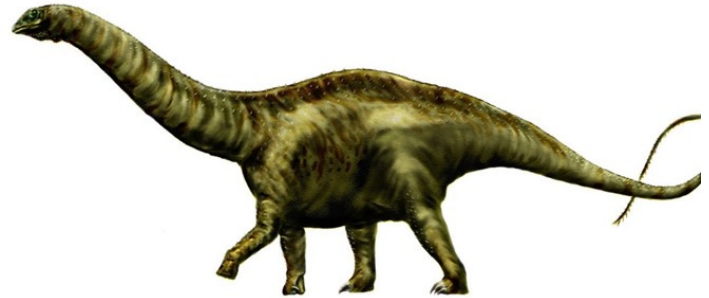


Picture from www.angelfire.com/mi/dinosaurs/images/casts/ceratosaurus_skeleton_cast_2.jpg

Apatosaurus

Apatosaurus is one of the most iconic dinosaurs to have been discovered. It also has perhaps one of the most storied histories of any prehistoric animal. For many years there were two similar dinosaurs that were recognized by the public; *Apatosaurus* and *Brontosaurus*. *Brontosaurus* was featured in many popular stories and books about dinosaurs, especially for children, and became very well known. In 1901, however, right here in Colorado's Grand Valley the story of *Apatosaurus* and *Brontosaurus* took a different turn. Paleontologist Elmer Riggs from Chicago's Field Museum was hunting for dinosaurs. Upon finding a skeleton going into a cliff at what is now Dinosaur Hill in Fruita, Riggs realized that he had found something unique. Back in Chicago, Riggs finally published his findings. *Apatosaurus* and *Brontosaurus* were not different animals at all, but instead were the same. Since *Apatosaurus* had been named first that name took priority and the name *Brontosaurus* was relegated to history books.

That is not the end of the story, however! In



2015 paleontologist Emanuel Tschopp and colleagues used new technology to analyze fossils that had been classified as *Apatosaurus*, along with some of its relatives. Using technology not available to Riggs, Tschopp and his co-authors found that differences in the bones of *Apatosaurus* and other sauropods meant that *Brontosaurus* was distinct! Scientists had mistakenly thought it was not a different animal since 1903.

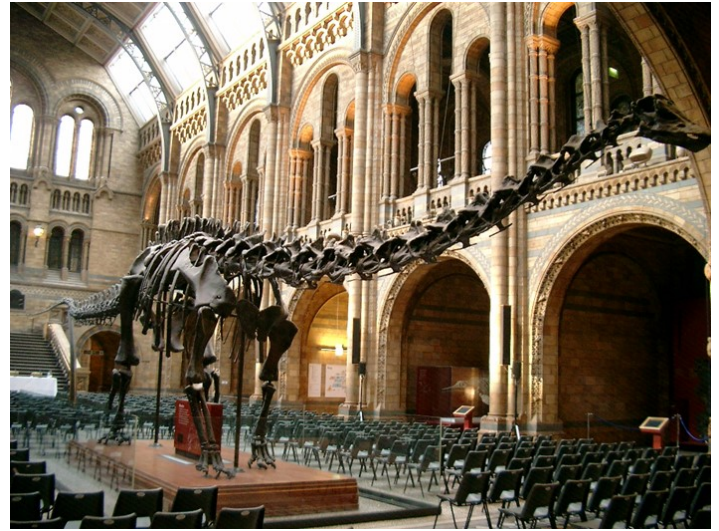
At the Mygatt-Moore Quarry in western Mesa County, *Apatosaurus louisae* is the most commonly found herbivorous (plant-eating) dinosaur.

ADD MORE



Diplodocus

Diplodocus was a relative of the more-common *Apatosaurus* and generally looked similar. Research by Museums of Western Colorado scientist Dr. Julie McHugh has recently shown that the teeth of *Apatosaurus* grew at a different rate than those of *Diplodocus*. That means that although these two dinosaurs looked alike, they were eating different things; this may account for why *Apatosaurus* is so common in the quarry while almost no *Diplodocus* bones have been found at MMQ to date. Did *Diplodocus* avoid marshy areas? Did *Apatosaurus* prefer them? Was it a seasonal watering hole and *Diplodocus* wasn't in the area when *Apatosaurus* was? All of these are possible explanations to the mystery of why *Diplodocus* is rare and *Apatosaurus* is common, but without a time machine we may never know for



sure. Future fieldwork may help us answer these questions, however.

ADD MORE

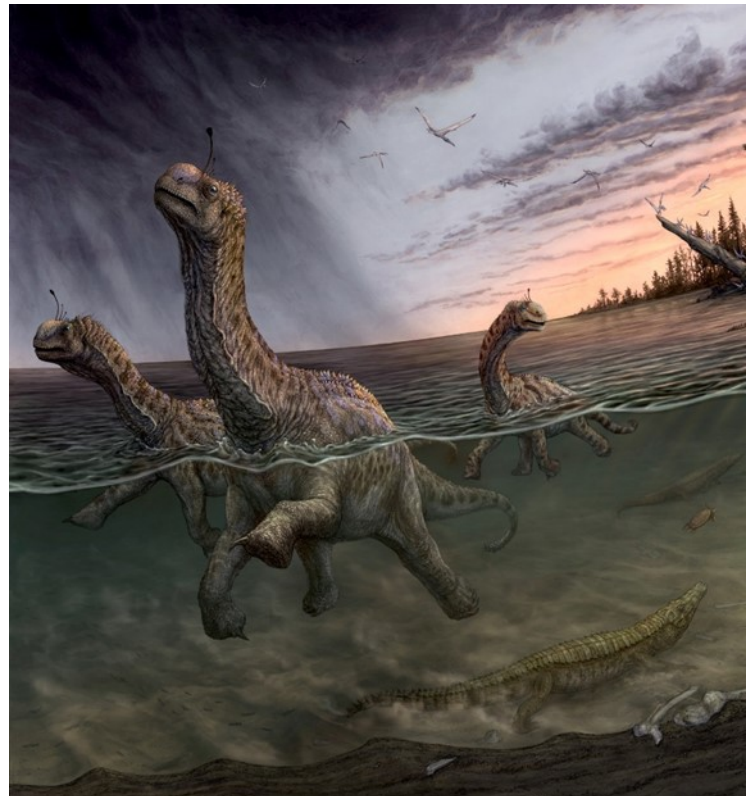


Camarasaurus

Camarasaurus is the most common sauropod dinosaur from the Morrison Formation, a Late Jurassic deposit of floodplain sediment, river channels, and dry salt pans. *Camarsaurus* means “chambered lizard,” which is a reference to the pneumatic cavities (or chambers) in its spine. These hollows were likely connected to its respiratory system in the same manner as the air sacs of birds and crocodiles are today.

Camarasaurus was in some ways the prototypical sauropod. Large without being a true giant (most specimens are around 50 feet in length), having a long neck and tail, and with a rather generalized sauropod head, *Camarasaurus* sometimes is used by paleontologists as a stand-in for what earlier sauropods may have looked like. *Camarasaurus* had a deep skull and jaw, with broad spoon-shaped teeth that would have been good for stripping branches, plucking tough vegetation from the ground, and plucking conifer cones.

At the Mygatt-Moore Quarry in western Mesa County, only a handful of *Camarasaurus* fossils have been found.



Mymoorapelta

Mymoorapelta, first discovered at Mygatt-Moore, is one of the rarest dinosaurs from the Mygatt-Moore Quarry, with only the remains of two individuals being discovered so far. Related to other famous dinosaurs like *Ankylosaurus*, *Mymoorapelta* is the oldest ankylosaur discovered anywhere in the world! Named in 1994 by scientists from Colorado and Utah, *Mymoorapelta* changed what scientists thought they knew about armored dinosaurs. Previous to their discovery it had been thought that the only armored dinosaurs in the Late Jurassic of North America were things like *Stegosaurus* and its kin. With the discovery of *Mymoorapelta*, our understanding of armored dinosaur relationships and evolution had to change. It became clear that ar-

mored dinosaurs had split into stegosaurs and ankylosaurs long before the previously understood date.

Mymoorapelta's skull is incompletely preserved, but based on its relatives we can assume it had a short, broad muzzle with a beak and small, leaf-shaped teeth in its mouth. The picture you see here represents a mounted skeletal cast with a reasonable interpretation of where its armor was located. Since we have yet to find a fully articulated specimen of *Mymoorapelta*, we can only use inference based on its relatives to reassemble the armor into life positions.



Skeleton of *Mymoorapelta*. Photo by Reed Richmond.

Life in the Late Jurassic



Mygatt-Moore today and an artist's depiction of Mygatt-Moore, 152 million years ago. Art by Brian Engh.



Fossils of the Kit

MWC 8014



Cast in Kit – CCA 1



***Allosaurus* premaxilla tooth**

This is an *Allosaurus* premaxillary tooth—located in the front of the upper jaw—found out at the Mygatt-Moore Quarry (MMQ) in Mesa County.

MWC 1884



Cast in Kit – CCA 2



***Allosaurus* lateral tooth**

This is an *Allosaurus* lateral tooth. It would have been located on the side of the mouth.

Fossils of the Kit

Cast in Kit – CCA 3



***Allosaurus* lateral tooth with root**

The presence of the root indicates that this tooth was still attached to the jaw when the *Allo-saurus* died. The tooth later fell out of the jaw when the periodontal ligaments decayed.

MWC 5967



***Ceratosaurus* premaxillary tooth**

The ridges (or flutes) tell us that this tooth came from the carnivore *Ceratosaurus*.

Cast in Kit – CCA 5



Fossils of the Kit

MWC 5823



Cast in Kit – CCA 4



***Ceratosaurus* teeth**

These teeth are from a large meat-eating dinosaur called *Ceratosaurus*. *Ceratosaurus* is known from Colorado, Wyoming, and Utah. One species of *Ceratosaurus*, *C. magnicornis* has only been found in the Grand Valley and is the official dinosaur of the City of Fruita. *Ceratosaurus* teeth tend to be more blade-like than those of *Allosaurus* (see CCA 4) while the front teeth of *Ceratosaurus* tend to have strange ridges. Scientists are not sure what these ridges were used for but it is possible that they strengthened the teeth. Similar ridges are seen in modern crocodiles as well as fossils such as *Spinosaurus* and the dolphin-like ichthyosaurs.

Cast in Kit – CCA 6



Fossils of the Kit

MWC tooth



Cast in Kit – CCA 7



***Apatosaurus* teeth**

The teeth of *Apatosaurus* are generally small and peg-like, which is thought to be an adaptation for stripping vegetation off of low-lying plants with smaller leaves or needles.

MWC tooth 3897



Cast in Kit – CCA 8



Fossils of the Kit

MWC tooth 05.1



Cast in Kit – CCA 10



Cast in Kit – CCA 11



Fossils of the Kit

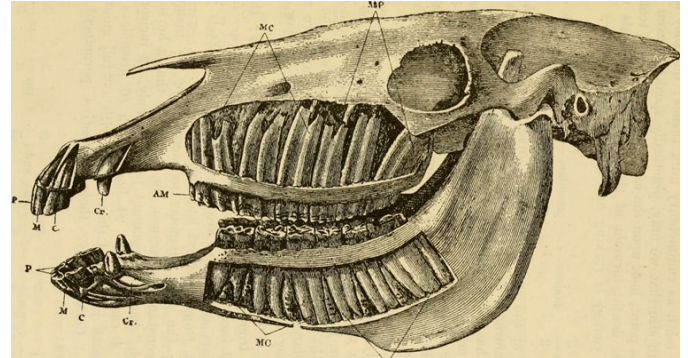
Cast in Kit – CCA 9



***Camarasaurus* teeth**

The teeth of *Camarasaurus* are broad and spatula-shaped. There are several examples of *Camarasaurus* teeth, which would have been hidden behind a beak during life, in this kit. **CCA 10** represents a newly-erupted tooth that has not been worn yet. **CCA 9** is a tooth that has seen some wear but was still attached to the animal's jaw. **CCA 11** is a very worn tooth that was still in the animal's jaw when it died, as evidenced by its root, and **CCA 8** represents a very worn, shed tooth that has dropped out of the animal's mouth before the animal died.

Inferring Fossil Diets



Carnivores' Teeth

In both mammals (top) and reptiles (bottom), carnivorous animals tend to have sharp, piercing teeth. This allows these animals to bite, hold on to, and subdue prey animals. Their sharp teeth also aid in eating their prey by crushing, slicing, and ripping.

Herbivores' Teeth

The teeth of herbivores, by contrast, tend to be more varied. The flat, grinding teeth of animals like horses (top), cows, and camels are contrasted with other mammalian herbivores like beavers, rabbits

Inferring Fossil Diets

MWC 5823



MWC tooth



to do that, however, we need to understand the types of plants that existed at the time of the animals we are trying to understand. To make matters trickier, many of the plants we have today (like grasses, flowers, and fruit trees) didn't exist in the Jurassic Period. This next section covers many of the major plants found in the Upper Jurassic Morrison Formation. Many of these have been found here in western Colorado, while others are from the same age rocks in neighboring states. Use these plant pictures as guides to help determine what the herbivorous animals of the Mygatt-Moore Quarry ate.

Fossil Teeth

Because of what we know about modern animals and their teeth, we are able to interpret the diets of extinct animals as well, based on their teeth. Carnivores are general going to be easy to identify. Herbivores, though, can be a bit more tricky. Just like today, animals in the past were eating many different types of plants. Before we are able

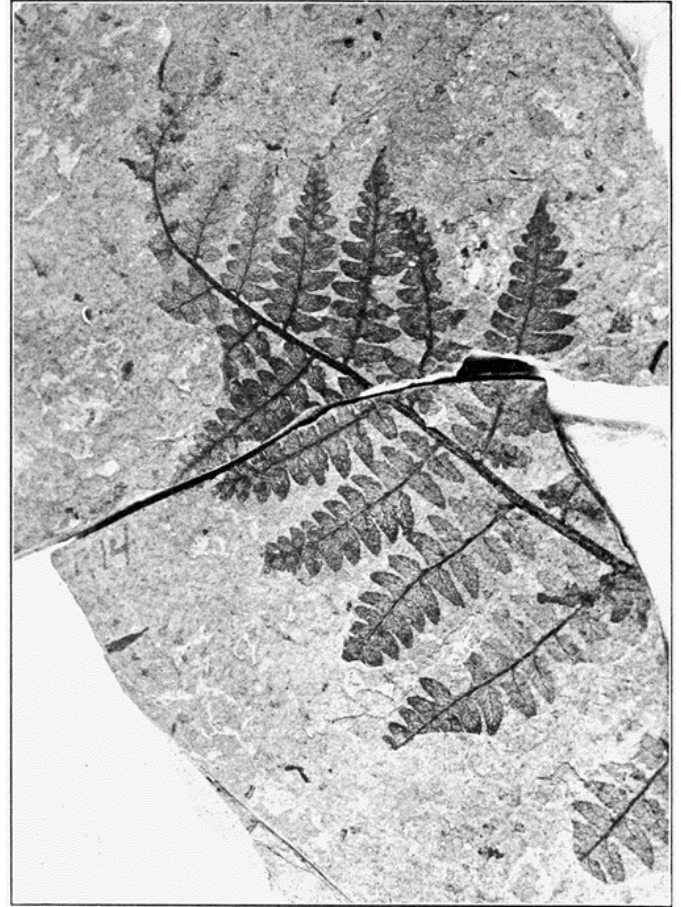
Fossil and Modern Club Mosses



Club Mosses

Club mosses are an ancient group of seedless vascular plants that reproduce by spores. Common throughout the Paleozoic and Mesozoic, they began to dwindle in importance during the late Mesozoic with the rise of the flowering plants.

Modern and Fossil Ferns



Ferns

Ferns, like club mosses, are vascular plants that reproduce with spores. They are common today in forests and in the past were a key part of the groundcover before the evolution of grasses and flowering plants during the Cretaceous.

Fossil and Modern Horsetails



Horsetails

Found near sources of water, horsetails are vascular plants that made up a large part of the diet of many dinosaurs.

Modern and Fossil Cycads



Cycads

Cycads, sometimes known as Sego Palms, are seed-bearing vascular plants that resemble (but are not related to) palm trees. They came in many different sizes during the Paleozoic and Mesozoic eras and filled the size role of many bushes today.

Fossil and Modern Ginko



Ginkos

Ginkos are broadleafed gymnosperm trees that were plentiful during the Mesozoic and still thrive today. As with many plants of the past, however, the evolution of protected seeds in angiosperms led to a decline in their diversity and abundance.

Modern and Fossil Dawn Redwood



Dawn Redwoods

Dawn redwoods were first described as fossils from the Mesozoic era but did in fact survive through to today. They are one branch of the conifers (cone-bearing evergreens) that existed during the Paleozoic and Mesozoic Eras and made up the bulk of the forests during those times

Fossil and Modern Monkey Puzzle Tree



Monkey Puzzle

Another unusual conifer with intricate branch/needle arrangements, Monkey Puzzle trees still exist today.

4th Grade Lesson

What Does It Eat?

Nature of Science: Ask testable questions and make a falsifiable hypothesis about using properties in perform separations, and design a method to find an answer. (DOK 2-4)

Background Knowledge:

This activity is designed to connect students to the natural history of the Grand Valley. Students will be able to make connections between modern and prehistoric ecosystems in regards to predators and prey, as well as understand that different types of teeth have evolved to eat different foods.

Grade Level: 4	Learning Event: Using casts of teeth to determine what animals of the past ate.
<p>Learning Objective/Target: Just like today, animals of the past consumed different foods. The different dental adaptations between animals living in the same time and place enabled them to eat different food sources, allowing them to thrive, reproduce, and pass their genes down to the next generation.</p> <p>S2 C1 EO a. Use evidence to develop a scientific explanation of what plants and animals need to survive (DOK 1-3) S2 C1 EO b. Use evidence to develop a scientific explanation for similarities and/or differences among different organisms (species) (DOK 1-3) S2 C1 EO c. Analyze and interpret data representing variation in a trait (DOK 1-2) S2 C1 EO d. Examine, evaluate, question, and ethically use information from a variety of sources and media to investigate questions about characteristics of living things (DOK 1-2) S2 C2 EO a. Use evidence to develop a scientific explanation for: 2. What conclusions can be drawn from similarities between fossil evidence and living organisms (DOK 1-3) S2 C2 EO c. Evaluate whether reasoning and conclusions about given fossils are supported by evidence (DOK 1-3)</p>	<p>Essential Questions:</p> <ul style="list-style-type: none"> • What similarities do the dinosaurs share with modern animals? • How can understanding the present help us interpret the past? • How can small variations in physical characteristics lead to large changes in survival?

4th Grade Lesson

Materials/Resources: <ul style="list-style-type: none"> - <i>Allosaurus</i> tooth casts (CCA 1, CCA 2, CCA 3) - <i>Camarasaurus</i> tooth casts (CCA 8, CCA 9, CCA 10, CCA 11) - <i>Ceratosaurus</i> tooth casts (CCA 4, CCA 5, CCA 6) - <i>Apatosaurus</i> tooth cast (CCA 7) - "What Does It Eat" PowerPoint presentation (on flash drive) - <i>Camarasaurus</i> Skull PDF (on flash drive) 	Assessment Options: <ul style="list-style-type: none"> • Presentation of diet hypothesis to class • Peer review of diet hypotheses by classmates
<p>PREPARE AHEAD OF TIME: Review the appropriate fossil casts and the PPT going over dietary choices before going out to Mygatt-Moore Quarry. There is also a brief video on the flash drive associated with the activity that reviews the animals and plants from the Jurassic of the area. Students will use casts of fossils from the Morrison formation in groups.</p> <p>Suggested Procedure:</p> <ol style="list-style-type: none"> 1. Background: Describe how teeth can be used to determine what animals used to eat. <ul style="list-style-type: none"> Ask students to explain what herbivore and carnivore teeth look like Give examples of modern organisms and their teeth Explain how animals that eat similar things can have different-shaped teeth to take advantage of different prey or different plants/parts of the same plant Model how to describe the teeth in basic terms, such as comparisons to everyday objects (pencils, spoons, knives) 2. Take students to Mygatt-Moore and review the fossils in the kit on-site <ol style="list-style-type: none"> a. Explain to students that they will have to examine and describe the teeth provided with the kit while on the trip b. Walk Trail Through Time to the <i>Camarasaurus</i> skeleton c. Have students identify which teeth in the kit are from <i>Camarasaurus</i>, based on the teeth impressions (see <i>Camarasaurus</i> Skull PDF) <p>Have students explain to each other and to instructor why non-<i>Camarasaurus</i> teeth belong to different animals</p> <p>Have students justify their conclusions about the teeth of <i>Allosaurus</i>, <i>Apatosaurus</i>, and <i>Ceratosaurus</i> (i.e. serrations, size, shape, pointed tip, etc.).</p> <p>Back in classroom:</p> <ul style="list-style-type: none"> Review the "What Does It Eat" PowerPoint with the class Students need to sort the teeth into broad categories (carnivore, herbivore) based on fieldtrip activities Students should justify their categorization Students then need to hypothesize what specific plants <i>Camarasaurus</i> was eating 4. Ask students/groups to justify their hypotheses to each other <ol style="list-style-type: none"> a. This can be out loud, in a chart, or in a written format b. Explain to students that science isn't about 100% agreement all the time (as students will likely have disagreements about things). Students should take away that tooth shape can be used by paleontologists to interpret diet, and that small differences in tooth shape can indicate a big difference between two closely related species diets. 	
Resource Links: <ul style="list-style-type: none"> • Video on Flash Drive. 	Speaking & Listening Connections: <ul style="list-style-type: none"> • Students should be presenting their diet hypotheses to the class • Students should be critically listening to their classmates in order to assess the strength of their arguments
Extension: <ul style="list-style-type: none"> • Students write a letter to biologist or paleontologist, explaining why they think a certain prehistoric animal they studied ate what it did. 	Teacher Notes:

7th Grade Lesson

Nature of Science: Ask testable questions and make a falsifiable hypothesis about using properties in perform separations, and design a method to find an answer. (DOK 2-4)

Background Knowledge:

This activity is designed to connect students to the natural history of the Grand Valley. Students will be able to make connections between modern and prehistoric ecosystems in regards to predators and prey, as well as understand that different types of teeth have evolved to eat different foods.

Grade Level: 7	Learning Event: Using casts of teeth to determine what animals of the past ate.
<p>Learning Objective/Target: Just like today, animals of the past consumed different foods. The different dental adaptations between animals living in the same time and place enabled them to eat different food sources, allowing them to thrive, reproduce, and pass their genes down to the next generation.</p> <p>S2 C1 EO a. Develop, communicate, and justify an evidence-based explanation for why a given organism with specific traits will or will not survive to have offspring in a given environment (DOK 1-3)</p> <p>S2 C1 EO b. Analyze and interpret data about specific adaptations to provide evidence and develop claims about differential survival and reproductive success (DOK 1-3)</p> <p>S2 C1 EO c. Use information and communication technology tools to gather information from credible sources, analyze findings, and draw conclusions to create and justify an evidence-based scientific explanation (DOK 1-2)</p> <p>S2 C5 EO a. Interpret and analyze data from the fossil record to support a claim that organisms and environments have evolved over time (DOK 1-2)</p> <p>ELA 1.2 - Small and large group discussions rely on active listening and the effective contributions of all participants</p> <p>ELA 4.1 Answering a research question logically begins with obtaining and analyzing information from a variety of sources</p> <p>ELA 4.2 Logical information requires documented sources</p>	<p>Essential Questions:</p> <ul style="list-style-type: none"> • What similarities do the dinosaurs share with modern animals? • How can understanding the present help us interpret the past? • How can small variations in physical characteristics lead to large changes in survival?

7th Grade Lesson

Materials/Resources:

- *Allosaurus* tooth casts (CCA 1, CCA 2, CCA 3)
- *Camarasaurus* tooth casts (CCA 8, CCA 9, CCA 10, CCA 11)
- *Ceratosaurus* tooth casts (CCA 4, CCA 5, CCA 6)
- *Apatosaurus* tooth cast (CCA 7)
- "What Does It Eat" PowerPoint presentation (on flash drive)
- *Camarasaurus* Skull" PDF
- Measurement worksheet (on flash drive "Measurement Worksheet_Grade7.docx")
- *Students need copies of measurement worksheet
- Ruler template (on flash drive "Ruler – printable.pdf")
- *Students need copies of ruler template
- Video about dinosaur diets (on flash drive – "DJ Teeth")

Assessment Options:

- Presentation of diet hypothesis to class
- Peer review of diet hypotheses by classmates

PREPARE AHEAD OF TIME:

Review the appropriate fossil casts and the PPT going over dietary choices before going out to Mygatt-Moore Quarry. There is also a brief video on the flash drive associated with the activity that reviews the animals and plants from the Jurassic of the area. Students will use casts of fossils from the Morrison formation in groups. Students should use rulers or paper scale bars (the template for the second is provided on the flash drive).

Suggested Procedure:

1. Background: Describe how teeth can be used to determine what animals used to eat.
 - Ask students to explain what herbivore and carnivore teeth look like
 - Give examples of modern organisms and their teeth
 - Explain how animals that eat similar things can have different-shaped teeth to take advantage of different prey or different plants/parts of the same plant
 - Show students how to measure and describe the teeth
2. Take students to Mygatt-Moore and review the fossils in the kit on-site
 - Explain to students that they will have to examine and measure the teeth provided with the kit
 - Examinations will occur in the field, measurements will happen in the classroom after the field trip
- b. Walk Trail Through Time to the *Camarasaurus* skeleton
- c. Have students identify which teeth in the kit are from *Camarasaurus*, based on the teeth impressions (see "*Camarasaurus* Skull" PDF)
- d. Have students explain orally to each other and to instructor why non-*Camarasaurus* teeth belong to different animals
- e. Have students justify their conclusions about the teeth of *Allosaurus*, *Apatosaurus*, and *Ceratosaurus* (i.e. serrations, size, shape, pointed tip, etc.).
- f. Have students begin to formulate general ideas about whether *Apatosaurus* and *Camarasaurus* were eating the same types of plants; similar discussions should be had about *Allosaurus* and *Ceratosaurus*.
 - Back in classroom:
 - Each group should receive copies of the measuring worksheet and a ruler/scale print out
 - Students need to first sort the teeth into broad categories (carnivore, herbivore) based on fieldtrip activities
 - Review the "What Does It Eat" PowerPoint with the class
 - Students then need to hypothesize what specific food sources the animal was eating (specific animals or types of plants, based on their work with the fossils in the kit and the PPT)
 - Students should mark their measurements down on their measurement worksheets
4. Ask students/groups to justify their hypotheses to each other.
5. Explain to students that science isn't about 100% agreement all the time (as students will likely have disagreements about things). Students should take away that tooth shape can be used by paleontologists to interpret diet, and that small differences in tooth shape can indicate a big difference between two closely related species diets.

High School Lesson

****Be sure to refer to the “Students will know” section of your unit plan for crucial concepts that should be a part of teaching and learning in this unit.**

Background Knowledge:

This activity is designed to have students understand how predators and prey interacted in the past and how we are able to deduce those interactions. Students will be able to make connections between modern and prehistoric ecosystems in regards to predators and prey, as well as understand how different types of teeth have evolved to eat different foods because of selective pressures based on energy and nutritional requirements of the animals.

Grade Level: High School	Learning Event: Analyzing data in order to draw conclusions about the natural history of fossil specimens.
<p>Learning Objective/Target: Just like today, animals of the past consumed different foods. The different dental adaptations between animals living in the same time and place enabled them to eat different food sources, allowing them to thrive, reproduce, and pass their genes down to the next generation. Over time, geological forces have exposed fossils on the surface of the Earth that allow us to interpret these interactions of the past.</p> <p>Standards:</p> <p>S2 C1 EO a. Analyze how energy flows through trophic levels (DOK 1 – 2)</p> <p>S2 C1 EO b. Evaluate the potential ecological impacts of a plant-based or meat-based diet (DOK 2)</p> <p>S2 C1 EO d. Develop, communicate, and justify an evidence-based scientific explanation showing how ecosystems follow the laws of conservation of matter and energy (DOK 1-3)</p> <p>S2 C1 EO e. Define and distinguish between matter and energy, and how they are cycled or lost through life processes (DOK 1-2)</p> <p>S2 C2 EO d. Examine, evaluate, question, and ethically use information from a variety of sources and media to investigate ecosystem interactions (DOK 1-2)</p> <p>S2 C4 EO b. Discuss the interdependence of autotrophic and heterotrophic life forms such as depicting the flow of a carbon atom from the atmosphere, to a leaf, through the food chain, and back to the atmosphere (DOK 1-2)</p> <p>S2 C9 EO d. Analyze and interpret data on how evolution can be driven by three key components of natural selection – heritability, genetic variation, and differential survival and reproduction (DOK 1-3)</p>	<p>Essential Questions:</p> <ul style="list-style-type: none"> • How did different tooth forms allow animals of the past to get energy and nutrients from different food sources? • How can fossils inform us about how ancient life was similar and different from modern life? • How can small variations in physical characteristics lead to large changes in survival? • How can physical processes on the Earth expose or destroy evidence of past life?

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<p>S3 C1 EO a. Develop, communicate, and justify an evidence-based scientific explanation addressing questions about Earth's history (DOK 1-3)</p> <p>S3 C1 EO b. Analyze and interpret data regarding Earth's history using direct and indirect evidence (DOK 1-2)</p> <p>S3 C1 EO d. Seek, evaluate, and use a variety of specialized resources available from libraries, the Internet, and the community to find scientific information on Earth's history (DOK 1-2)</p> <p>S3 C1 EO e. Examine, evaluate, question, and ethically use information from a variety of sources and media to investigate the history of the universe, solar system and Earth (DOK 1-2)</p> <p>S3 C3 EO b. Analyze and interpret data on plate tectonics and the geological, physical, and geographical features of Earth (DOK 1-2)</p>	<ul style="list-style-type: none"> •
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<p>Materials/Resources:</p> <ul style="list-style-type: none"> - <i>Allosaurus</i> tooth casts (CCA 1, CCA 2, CCA 3) - <i>Ceratosaurus</i> tooth casts (CCA 4, CCA 5, CCA 6) - <i>Apatosaurus</i> tooth casts (CCA 7) - <i>Camarasaurus</i> tooth casts (CCA 8, CCA 9, CCA 10, CCA 11) - History of Mygatt-Moore presentation (on flash drive—"History of Mygatt-Moore" PowerPoint) - "Camarasaurus Skull" PDF - "What Does It Eat" PowerPoint presentation (on flash drive) - Measurement worksheet (on flash drive "Measurement Worksheet_HighSchool" Word Doc) *Students need copies of measurement worksheet - Ruler template (on flash drive "Ruler – printable.pdf") *Students need copies of ruler template - Video about dinosaur diets featuring Robert 'Rob' Gay (on flash drive – "DJ Teeth") 	<p>Assessment Options:</p> <ul style="list-style-type: none"> • Presentation of diet hypothesis to class • Peer review of diet hypotheses by classmates • Approximately 500-word essay supporting or disproving their dietary hypothesis based on reliable sources
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PREPARE AHEAD OF TIME:

Teachers review the two PowerPoints, "History of Mygatt-Moore" and "What Does It Eat," as well as the appropriate fossil casts. Students will use casts from the Morrison formation at the Mygatt-Moore Quarry in Mesa County. Students should use rulers or paper scale bars (the second is provided on the flash drive) to measure tooth casts during post-field trip activities.

Suggested Procedure:

1. Background – In-Class: Describe how teeth can be used to determine what animals used to eat.
 - Ask students to explain what herbivore and carnivore teeth look like
 - Remind how animals that eat similar things can have different-shaped teeth to take advantage of different prey or different plants/parts of the same plant
 - Go over the history of the Mygatt-Moore Quarry (Present "History of Mygatt-Moore" PowerPoint)
 - Teachers might want to print "History of Mygatt-Moore" PowerPoint ahead of time to bring as a resource on field trip

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Teachers might also want to print out “*Camarasaurus* Skull” PDF for ease of locating the skull on the Trail through Time Field Trip to Mygatt-Moore Quarry
 Take students up to MMQ and talk about the quarry
 Take students up to the *Camarasaurus* skeleton on the Trail through Time. (First stop on the trail). Skeleton has been eroding out of channel sandstone.
 Students will locate skull impression. (See “*Camarasaurus* Skull” PDF for help locating)
 Show students teeth in kit. *Be sure to pocket or hide tooth identification guide found in kit.*
 Students will use casts from kit to compare with tooth impressions on *Camarasaurus* skull
 Have students identify which teeth in kit belong to *Camarasaurus*
 i.e. CCA 8, CCA 9, CCA 10, CCA 11
 Students should use rulers or calipers to measure tooth impressions and teeth in kits
 Students should develop a falsifiable hypothesis as to which teeth belong to herbivores

3. Post-field trip

a. Show students “What Does It Eat” PowerPoint

Students measure fossil tooth casts and record data on “Measurement Worksheet”

Mention that dinosaurs continually replaced their teeth, an adaptation that meant that they never had bad teeth. (That means dinosaurs never had to worry about cavities!)

Have students recall the different appearances of the four *Camarasaurus* teeth

Have students identify the least worn *Camarasaurus* tooth, i.e. CCA 10

Have students identify the teeth that were still in the dinosaurs’ jaws at death. (The ones with roots: CCA 3, CCA 9, CCA 11)

Have students estimate total root length based on tooth length using teeth with full roots (CCA 3, CCA 11)

Students should hypothesize how this tooth replacement adaptation led to an increase in fitness in the dinosaurs that first showed this adaptation

c. Students should make a poster showing how they think energy and matter was cycled in the Jurassic ecosystem from the sun (energy) and soil (nutrients) to plants, herbivores, carnivores, and then back into the soil (or lost as heat)

d. Have students present their ecosystem poster to the class and defend it from peer (student) review

e. Explain to students that science isn’t about 100% agreement all the time (as students will likely have disagreements about things). Students should take away that scientists often have to work with limited data and have to draw conclusions based on the data they have available. Students should also take away that tooth shape not only indicates diet but can be used to infer trophic relationships and that energy and matter cycled through ancient ecosystems in a manner similar to modern ones. In addition, without erosion and conservation, we would not have evidence of these ancient ecosystem interactions.

<p>Resource Links:</p> <ul style="list-style-type: none"> • Video on Flash Drive <p>Video about nutrient recycling: “Taphonomy in action!” https://www.youtube.com/watch?v=qXelh2_9j5Q</p>	<p>Speaking & Listening Connections:</p> <ul style="list-style-type: none"> • Students should be presenting their poster and trophic relationship hypotheses to the class • Students should be critically listening to their classmates in order to assess the strength of their arguments and ask insightful questions about their conclusions
<p>Extension:</p> <ul style="list-style-type: none"> • Students use peer reviewed scientific articles to assess whether their hypotheses of trophic interactions have support in the scientific community 	<p>Teacher Notes:</p>

7th Grade Measurement Worksheet

Measurement Worksheet

To complete this exercise, use your printed ruler to measure the teeth from the kit. Use the picture guide below to help you figure out length (A) and height (B). The width of the tooth will be measured across the base, at a right angle to the length. Make observations and notes to help you compare the teeth as well, in order to figure out their diet.



Tooth	Height in CM	Width in CM	Length in CM	Notes
<i>Allosaurus</i> tooth cast (CCA 1)				
<i>Allosaurus</i> tooth cast (CCA 2)				
<i>Allosaurus</i> tooth cast with root (CCA 3)				
<i>Ceratosaurus</i> lateral tooth cast (CCA 4)				
<i>Ceratosaurus</i> tooth cast, broken (CCA 5)				
<i>Ceratosaurus</i> anterior tooth cast (CCA 6)				
<i>Apatosaurus</i> tooth cast (CCA 7)				
<i>Camarasaurus</i> tooth cast, worn (CCA 8)				
<i>Camarasaurus</i> tooth cast with partial root (CCA 9)				
<i>Camarasaurus</i> tooth cast, not worn (CCA 10)				
<i>Camarasaurus</i> tooth cast with root (CCA 11)				

High School Measurement Worksheet

Measurement Worksheet

To complete this exercise, use your printed ruler to measure the teeth from the kit. Use the picture guide below to help you figure out length (A) and height (B). The width of the tooth will be measured across the base, at a right angle to the length. Make observations and notes to help you compare the teeth as well, in order to figure out their diet.



Tooth	Height in CM	Width in CM	Length in CM	Root Length in CM	Notes
<i>Allosaurus</i> tooth cast (CCA 1)					
<i>Allosaurus</i> tooth cast (CCA 2)					
<i>Allosaurus</i> tooth cast with root (CCA 3)					
<i>Ceratosaurus</i> lateral tooth cast (CCA 4)					
<i>Ceratosaurus</i> tooth cast, broken (CCA 5)					
<i>Ceratosaurus</i> anterior tooth cast (CCA 6)					
<i>Apatosaurus</i> tooth cast (CCA 7)					
<i>Camarasaurus</i> tooth cast, worn (CCA 8)					
<i>Camarasaurus</i> tooth cast with partial root (CCA 9)					
<i>Camarasaurus</i> tooth cast, not worn (CCA 10)					
<i>Camarasaurus</i> tooth cast with root (CCA 11)					