AD**VENTURE 360**
Adventures in Learning

Paleo X Field School

Thank you for joining this summer's Paleo X Field School. Included is the information you will need for your program including daily itinerary, supplies, lodging, meals, background information on the Hell Creek Formation, geology, Bureau of Land Management, and paleontology terms. This information will help you to better understand the topics that are discussed in the field.

Again, thanks for joining us and I look forward to seeing you in Montana.

Sincerely,

Ron K. Giesler, Director
AD**VENTURE 360**
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Paleo X Field School

PROGRAM SUPPLIES

CHECKLIST OF THINGS TO BRING WITH YOU

Clothing

___ Brimmed hat even if you never wear a hat, wear a hat

___ Comfortable lightweight hiking shoes or boots with good tread an that lace above the ankle for support. Be sure to break them in before arriving in Montana!

___Lightweight pants and/or shorts. Zip off pants work really well

___Lightweight long- and short-sleeved shirts

___Light jacket, windbreaker, sweater or sweatshirt; lightweight rain poncho

___Small notebook or field journal and pencils

___Two 28-ounce water bottles and small backpack or daypack

*Laundry facilities are available in Jordan.

Personal Items

___ Underclothes, padded or thick socks, sleepwear/robe

___ Sandals or tennis shoes for evening activities (these are not appropriate for use in the field)

___ Sunglasses, alarm clock, brush, chap stick, etc.

___ Toiletries: toothbrush and toothpaste, tissues, etc

___ Sunscreen (SPF 30 or higher is recommended) and insect repellent

___ Prescription medications, over-the-counter medications you commonly use (aspirin, Advil, EpiPen if needed, cold and allergy medications, antibiotic cream, etc)

Field Tools-Commonly used field tools if you would like to bring your own.

___Rock or brick hammer

___Screwdriver or garden tool

___Old toothbrush

___Small ruler for scale

___GPS, 2-way radio with subchannels

___Light gardening or leather gloves

Optional Items

___Camera, binoculars
___Walking stick
___Books or other reading material

*Note: The more things you bring the more things that could be lost in the badlands.

AD**VENTURE 360** will provide

- Permits
- Maps
- Complete first aid supplies
- All survey and excavation supplies
- Any additional materials needed

ADVENTURE 360
Adventures in Learning

Paleo X Field School

DAILY ITINERARY

Day 1 – Arrive in Jordan MT

Group arrives in Jordan, Montana. Meet at Summit Corral for group dinner at **6:00 pm**. Staff introductions, orientation and weekly overview. Included Meals: D

Day 2 – Jordan MT-Field Sites

6:30-7:30 Breakfast buffet at the Garfield Motel. Meet on veranda for breakfast and to pack lunch and overview of the day's activities. Transport to field site. Orientation on field safety, tool usage and fossil collection protocols. Morning GPS orientation, stratigraphy, fossil identification and prospecting around excavation site. Sack lunch in the field. Work on excavation site or continue prospecting. Dinner in town and evening presentation: "**Paleo X Fossil Collection Techniques"**. Included meals: B, L

Day 3 – Jordan MT-Field Sites

6:30-7:30 Breakfast buffet at the Garfield Motel. Meet on veranda for breakfast and to pack lunch and overview of the day's activities. Transport to field sites. Introduction to maps, fossil excavation and collection techniques. Sack lunch in the field. Option to excavate or continue to surface survey local sections in the badlands. Return to town for dinner and evening presentation: **"Geologic History & Stratigraphy of the Hell Creek Formation".** Included meals: B, L

Day 4 – Jordan MT-Field Sites

6:30-7:30 Breakfast buffet at the Garfield Motel. Meet on veranda for breakfast and to pack lunch and overview of the day's activities. Transport to field excavation and survey sites. Map and compass use, fossil excavation and surface surveying. Sack lunch in the field. Continue fossil excavation and surface surveying permitted sections in the badlands. Return to town for dinner and evening presentation: "**Measuring a Geologic Section**". Make a Jacob's staff. Included meals: B, L

Day 5 – Jordan MT-Field Sites

6:30-7:30 Breakfast buffet at the Garfield Motel. Meet on veranda for breakfast and to pack lunch and overview of the day's activities. Return to field sites for measuring stratigraphic layers around excavation site. Sack lunch in the field. Continue fossil excavation and surface surveying permitted sections in the badlands. Return to town for dinner and evening activity: **"Drawing a Stratigraphic Map"** and presentation **"Dinosaurs of the Hell Creek Formation"**. Included meals: B, L

Day 6 – Jordan MT-Field Sites

6:30-7:30 Breakfast buffet at the Garfield Motel. Meet on veranda for breakfast and to pack lunch and overview of the day's activities. Travel to field sites for fossil excavation and surface surveying permitted sections. Sack lunch in the field. Continue fossil excavation and surface surveying in the badlands. Return to town for group dinner and concluding activities. Included meals: B, L, D

Day 7 – Jordan MT-Billings MT

6:30-7:30 Breakfast buffet at the Garfield Motel. Program ends. Transport to Billings Logan International Airport for those with return flights. Included meals: B

*Subject to change. Each morning plan to meet at the AD**VENTURE 360** vehicles promptly at 8 a.m. for updates on daily schedule. In the event of rain, we will visit local museums to continue our exploration of paleontology.
*Meals: B=Breakfast, L=Lunch, D=Dinner

ADVENTURE 360
Adventures in Learning

Paleo X Field School

If you are arriving at the Logan International Airport in Billings

Meet our staff at the **Baggage Claim** section of the airport at the bottom of the escalators. Staff will meet you at the bottom of the escalators by 1:00 pm. Look for our Paleo X shirts. Plan your flights to arrive **before** 1:00 pm on the day of your arrival. We will then proceed to the airport restaurant for lunch (not included in fees).

At the end of the week, return transportation will be provided to the airport. Please plan for all return flights to leave **after** 1:00 p.m. on your departure day. All transportation after arriving at the airport is the responsibility of the individual.

If you are arriving in Jordan, MT

Please plan to arrive at the **Garfield Motel** before 5:00 p.m. Your room will be ready for you to check in upon your arrival. The first group activity will be dinner at the Summit Corral at 6:00 pm.

ADVENTURE 360
Adventures in Learning

Paleo X Field School

CONTACT INFORMATION

During the week, you will be staying at the:

Garfield Motel
Highway 200
Jordan, MT 59337
406.557.6215

Staff will be staying in rooms 18 and 19. If you need to contact staff, please use email, Facebook messenger or call the Garfield Motel. The Program Director can be contacted at 314.402.3612.

For emergencies contact the Garfield County Sheriff's Department: 406.557.2540

Cell phones are not reliable depending on your service provider (Verizon seems to work best). The motel does have wi-fi that supports internet-based communication.

Credit cards are accepted at both restaurants and the grocery store in town. However, there are some stores that accept cash only. There are ATM machines located in the restaurants and grocery store.

ADVENTURE 360
Adventures in Learning

Paleo X Field School

MEALS

Breakfast

A continental-style breakfast will be provided daily. Breakfast will be on the veranda of the Garfield Motel from 7:00-7:30 a.m. Examples of buffet items include:

Drinks:	Coffee, water, juice, milk, tea
Buffet:	English muffins, scrambled egg mix, bagels, toast, yogurt, hot and cold cereals, fruit, etc.

Lunch

Lunches are provided daily and can be packed between 7:30-8:00 a.m. Lunches will be picnic-style in the field at prospecting and excavation locations. Examples of food items include:

Meats:	Sliced lunchmeats (ham, turkey)
Condiments:	Mayonnaise, mustard, ketchup
Cheeses:	American and/or cheddar
Breads:	White, wheat
Chips:	Plain, sour cream and onion, etc.
Dessert:	Cookies, granola bars, etc.
Fruit:	Apples, oranges, bananas, etc.
Drinks:	Water and Gatorade or your own drink

Dinner (optional)

Evening dinners are on your own unless otherwise noted on the Daily Itinerary section. The first and last dinners are group dinners included in the program fees. There are several small restaurants and a grocery store in Jordan for dinner options. There is also a propane barbecue grill, airfryers, deep fryers and cooking utensils for guest use.

ADVENTURE 360
Adventures in Learning

Paleo X Field School

LOCAL CONDITIONS

Averages for the month of July

Average High	87°	Record High	112°
Average Low	55°	Record Low	31°
Average Rainfall	1.69”	Elevation	~2700 feet

Although the average temperatures are not that high, we can experience days when the temperatures reach the low 100s. Also, this is a high intensity, dry heat. Please be prepared.

Visit this link for local weather conditions and forecasts:
http://www.accuweather.com/en/us/jordan-mt/59337/weather-forecast/334204

Visit these links for further information about Jordan and Garfield County Montana:
http://www.visitmt.com/places-to-go/cities-and-towns/jordan.html
http://www.garfieldcounty.com/

ADVENTURE 360
Adventures in Learning

Paleo X Field School

OTHER ITEMS TO KNOW

This is a working program, not a tour. As participants, you will be experiencing similar daily activities as a paleontologist. Daily activities include walking, climbing hills, digging and carrying items. If at any time staff offers you water, you must take it. We are better prepared for the environment and your safety is our first concern.

Any motel incidentals including phone calls, room service or movie rentals are the responsibility of the participant.

The first group meal included in the fees is the evening group dinner in Jordan Montana. The last group meal included in the fees is breakfast on the day of departure.

Breakfasts and lunches are provided during the week. Dinners, unless otherwise noted in the Daily Itinerary section, are not included in the fees. Additional meals, drinks, snacks or alcoholic beverages are not included in fees.

You should know your own abilities. There may be a day when you want to stay in town and not go to the field. You are free to do this, however all meals and any transportation expenses are your responsibility.

ADVENTURE 360
Adventures in Learning

Paleo X Field School

ADDITIONAL BACKGROUND INFORMATION

The following information will help prepare you for your adventure.

Common Field Terms

- Articulated/Disarticulated-consisting of segments held together by joints/not held together by joints. In an articulated specimen, the fossilized bones remain located as in the living animal.

- BLM- (Bureau of Land Management) The BLM is responsible for carrying out a variety of programs for the management and conservation, of resources on 256 million surface acres, as well as 700 million acres of subsurface mineral estate. These public lands make up about 13 percent of the total land surface of the United States and more than 40 percent of all land managed by the Federal government. It is through the BLM that we get our surveying and excavation permits.

- Butte- An isolated hill or mountain with steep or precipitous sides, usually having a smaller summit area than a mesa.

- Champsosaurus-(pronounced CHAMP-so-SAWR-us) Champsosaurus was a long-jawed early reptile that lived during the late Cretaceous period through the Eocene period. This fish-eater was about 5 feet (1.5 m) long, and lived in rivers and swamps. It had powerful jaws in a very long, thin, toothed snout, four short legs, and a long tail which it used to propel itself in the water. Fossils have been found in Europe and North America. It was not a dinosaur. (Subclass Diapsida, Order Choristodera)

- Concretion--An accumulation of mineral matter formed around a center, or axis, of deposition after a sedimentary deposit has been laid down. Cementation consolidates the deposit as a whole, but the concretion is a body within host rock that represents local concentration of cementing material: enclosing rock is less firmly cemented than the concretion. Commonly spheroidal or disk-shaped and composed of such cementing agents as calcite, dolomite, or iron oxide.

- Coprolites- fossilized feces, or animal dung. They form an important class of objects studied in the field of paleontology.

- Coulee-A coulee (or coulée) is a deep steep-sided ravine formed by erosion, commonly found in the northwestern United States and southwestern Canada. Most coulees were originally formed during the rapid melting of the glaciers at the end of the last Ice age. Some coulees are dry for most of the year; others may contain small streams. The loose rocks at the base of the wall form what are called scree slopes. These are formed when chunks of the canyon wall give way in a rockslide.

- Dental battery-A set of hundreds of small teeth that are continually wearing out and being replaced. Many plant-eating dinosaurs had dental batteries.

- Gastrolith- A stone deliberately swallowed by an organism (usually an herbivore) and retained in the gut to cut and crush bulk food items.

- Hadrosaur Dinosaurs-The hadrosaur dinosaurs are known as the duck-billed dinosaurs due to the similarity of their head to that of modern ducks. In some genera, including Edmontosaurus, the whole front of the skull was flat and broadened out to form a beak, which was ideal for clipping leaves and twigs. However the back of the mouth contained thousands of teeth suitable for grinding food before it was swallowed. This feature has been hypothesized to have a been a crucial factor in the success of this group during the Cretaceous Period compared to the sauropods.

- Hell Creek Formation-A layer of rock that was deposited at the very end of the "age of dinosaurs", 67 to 65 million years ago. The formation is found in Montana, North Dakota and South Dakota. A rock layer of the same age is found further south, and goes by another name (The Lance Formation). In Canada, this same rock layer is called the Frenchman Formation and the Scollard Formation. All of these units were deposited by ancient rivers that flowed eastward into a large inland sea that ran from north-central Canada to the Gulf of Mexico. The rock layer that underlies the Hell Creek Formation is called the Fox Hills Formation, and the overlying layer is called the Tullock Formation (Paleocene). In the Dakotas, the overlying formation is called the Ludlow Formation. The famous K-T boundary, which separates the Cretaceous and Cenozoic, occurs as a discontinuous but distinct thin marker bed within the Hell Creek Formation near its top, giving the rock unit added scientific importance.

- K-Pg Boundary-Previously known as Cretaceous-Tertiary (K-T or KT) boundary, the K-Pg boundary is a period of massive extinction of species, about 65.5 million years ago. It corresponds to the end of the Cretaceous Period and the beginning of the Paleogene Period. (K is the traditional abbreviation for the Cretaceous period from Greek ‘kreta’ meaning chalky). The duration of this extinction event (like others) is unknown. Many forms of life perished (embracing approximately 50% of all genera), the most often mentioned among them being the dinosaurs. Many explanations for this event have been proposed, the most widely- accepted being the results of an impact on the Earth of an object from space.

- Micro-Sites-Areas where ancient streams have concentrated the bones, teeth and scales of small animals such as turtles, gars, crocodiles and mammals.

- Morphology-The study of form and structure of animals and plants and their fossil remains.

- Osteoderm—the bony deposits forming scales, plates or other structures in the dermal layers of the skin.

- Paleobiogeography-The branch of paleontology that deals with the geographic distribution of plants and animals in past geologic time, especially with regard to ecology, climate, and evolution.

- Paleoecology -The study of the relationships between ancient plants and animals and their environments.

- Phylogeny - A branching diagram showing the ancestral relations among species or other taxa. It shows, for each species, with which other species it shares its most recent ancestor.

- Raptor-A group of theropod dinosaurs closely related to birds.

- Scute-A horny, chitinous, or bony external plate or scale, as on the shell of a turtle or the underside of a snake.

- Stratigraphy-A branch of geology which studies rock layers (strata) and layering (stratification). It is primarily used in the study of sedimentary and layered volcanic rocks.

- Theropod-Any of numerous carnivorous dinosaurs of the Triassic to Cretaceous with short forelimbs that walked or ran on strong hind legs.

- Ceratopsian Dinosaurs- Meaning "horned faces", ceratopsian dinosaurs are a group of herbivorous, beaked dinosaurs that thrived in what are now North America, Europe, and Asia, during the Cretaceous Period, although ancestral forms lived earlier, in the Jurassic. The earliest known ceratopsian, *Yinlong downsi*, lived between 161.2 and 155.7 million years ago.[1] The last ceratopsian species became extinct in the Cretaceous–Paleogene extinction event, 66 million years ago.[1]

  Early members of the ceratopsian group, such as *Psittacosaurus*, were small bipedal animals. Later members, including ceratopsids like *Centrosaurus* and *Triceratops*, became very large quadrupeds and developed elaborate facial horns and frills extending over the neck. While these frills might have served to protect the vulnerable neck from predators, they may also have been used for display, thermoregulation, the attachment of large neck and chewing muscles or some combination of the above. Ceratopsians ranged in size from 1 meter (3 ft) and 23 kilograms (50 lb) to over 9 meters (30 ft) and 5,400 kg (12,000 lb). *Triceratops* is by far the best-known ceratopsian to the general public.

- Tyrannosaur-*Tyrannosaurus* meaning "tyrant lizard", is a genus of theropod dinosaurs. The species *Tyrannosaurus rex* (*rex* meaning "king" in Latin), commonly abbreviated to *T. rex*, is one of the most well-represented of the large theropods. *Tyrannosaurus* lived throughout what is now western North America, which then was an island continent named Laramidia. *Tyrannosaurus* had a much wider range than other tyrannosaurids. Fossils are found in a variety of rock formations dating to the Maastrichtian age of the upper Cretaceous Period, 68 to 66 million years ago. It was among the last non-avian dinosaurs to exist before the Cretaceous–Paleogene extinction event.

- Western Interior Seaway-- The Western Interior Seaway, also called the Cretaceous Seaway and the North American Inland Sea, was a huge inland sea that split the continent of North America into two halves during most of the early and mid-Cretaceous period.

ADVENTURE 360
Adventures in Learning

Paleo X Field School

FOSSILS AND FOSSILIZATION

Dr. Michael Morales
Emporia State University

INTRODUCTION

What we know about ancient life of the geologic past comes from fossils and the rocks that encase them. Data associated with a fossil, such as its age and the environment in which it was buried, are important factors in our understanding of Earth's ancient life. In this chapter, you will learn what a fossil is, how living organisms turn into fossils, and how to distinguish different kinds of fossil preservation.

FOSSILS

The term fossil comes from the Latin word *fossilis*, which means "something dug out of the ground". As originally used, the word fossil meant anything dug up, such as minerals, metals, old coins and pottery, etc. Since the 1 700s, however, the term has been restricted to its modern meaning. Fossils can be defined as the remains or traces of ancient life, usually preserved in rocks. The ancient life may be animals, plants, and fungi, or even microorganisms such as bacteria. The term subfossil is sometimes used to refer to body remains that are less than 10,000 years old (since the last ice age) and not or only partially petrified (Greek: "turned to stone"). It is important to note that human-made artifacts (arrowheads, pottery, etc.) and structures (buildings, roads, etc.), are not fossils. Fossils (including human fossils) are the realm of the science of paleontology (Greek: "the study of ancient existence"), whereas human-made artifacts and structures are the domain of archaeology. Fossils are generally divided into two major categories: body fossils and trace fossils.

Body Fossils

Body Fossils are preserved hard or soft parts of the body of an organism. The vast majority of body fossils are of hard body parts because they are much more resistant to decay prior to fossilization than are soft tissues. Another reason is that hard parts may not be consumed by predators and scavengers, or they may pass relatively intact through these animals' digestive systems, unlike soft parts which are generally broken down during digestion. Examples of body fossils include: Hard parts - bones, teeth, shells of animals; wood, cones, bark, seeds, and leaves of plants. Soft tissues - skin, muscles, hair, feathers, organs of animals; flowers, fruits, food roots of plants; the cell membrane of bacteria and other single celled organisms

Trace Fossils

Trace Fossils are the preserved indications or signs of ancient life without any actual body parts being preserved. The study of trace fossils is called paleoichnology (Greek: "the study of ancient tracks"). Trace fossils come in three categories: behavior, product, and somatic.

Behavior Trace Fossils

Behavior trace fossils are preserved indications of the behavior or activity of an organism. Examples include: 1. animal tracks and trails, 2. burrows, 3. dwellings, such as bird nests and mammal dens, 4. feeding indications, such as tooth marks by a predator on its prey's bones.

Product Trace Fossils

Product trace fossils are objects produced by an organism but not actually part of the body. Examples include: 1. coprolites (Greek: "feces stones") = fossilized dung, 2. regurgitated pellets (e.g., from owls), 3. gastroliths (Greek: "stomach stones") = rocks swallowed to grind food in the gizzard, 4. eggs.

Somatic Trace Fossils

Somatic trace fossils are molds/impressions and casts of all or part of the body of an organism, but without any actual body hard parts or soft tissues preserved. The term somatic means related to the body. Examples include: 1. internal and external molds and impressions of part or all of a body, such as dinosaur footprint tracks, impressions of fish scales, molds of clam shells; 2. internal or external casts of part or all of a body, such as casts of a braincase. Somatic (Greek: soma = "body") means "related to the body".

Sometimes a single preserved specimen is both a body fossil and a trace fossil at the same time. For example, a piece of petrified wood with tooth marks made by a gnawing beaver is a body fossil for the tree and a trace fossil for the beaver. Or, a fossilized egg with fossilized embryo bones inside is a body fossil for the embryo and a trace fossil for the adult mother who laid the egg.

BODY FOSSIL PRESERVATION

When a plant, animal, or microorganism dies, its body may become buried by waterborne or wind- blown sediments. Once buried, body parts may decay away, remain unaltered, or be altered by pressure, heat, and water chemistry of the surrounding sediments. Usually the sediments lithify into sedimentary rocks over time. If the buried body completely decays away during this process, then no body fossil is left. But if the body parts do not fully breakdown, then two major categories of body fossil preservation may result: unaltered and altered.

Unaltered Remains

Burial Without Change

The original organic substances of (usually hard) body parts are not changed after being buried by sediments. The fossils look and feel like they were living rather recently, even though they may be millions of years old.

Freezing

Ice box-like preservation of original hard and soft body parts. Example: Woolly mammoths preserved in Siberian permafrost (permanently frozen soil). This is the best way to preserve soft tissues, but it is rare and applies only to organisms of the last Ice Age.

Desiccation

Drying out of hard and soft body parts in arid climates produces a beef jerky-like preservation of the original organic substances. Body remains preserved in this way are called a desiccation mummy. After desiccation, the remains may be buried and undergo additional preservation processes that mineralize the dried organic material so the fossil is rock-like. This is a petrified mummy.

Impregnation

External and internal surfaces of (usually hard) body parts may become coated with tar or asphalt, such as at the Le Brea Tar Pits in Los Angeles. The fossil's original organic material usually remains unaltered. Also, natural embalming not involving tar, such as in peat bogs, occurs when body parts (hard and soft) become saturated with preserving chemicals from the surrounding boggy ground, thus preserving the body by producing a natural mummy. The body parts themselves may still contain their original organic material.

Altered Remains

Compression

If a fossil is flattened but body parts are still present, then it is called a compression. If flattening is associated with carbonization (see below), then the resulting fossils will be dark black; if not, then the fossil will be a color other than dark black, or a mixture of colors that may include some black. A compression is not a mold because a mold has no unaltered or altered body parts still present.

Carbonization

All elements of the body's original organic substances are removed except for carbon, which remains to reveal the dark black fossil's size and shape. Often this process results in a flattened black fossil (a carbonized compression, see above), but it can also result in a black fossil that is not flattened, such as three-dimensional coal.

Replacement

The original organic substance of the body part is removed, to be replaced by minerals (often calcite- or silica-based) that are dissolved in water percolating through the area. A molecule of the original organic substance is chemically taken away, and in its former position a mineral molecule is substituted, thus maintaining the fossils structure. Also, permineralization may or may not fill in the hollow spaces of the replaced fossil.

Permineralization

Hollow spaces in the body's structure are filled in with sediments or minerals, and the original organic substances either remain unaltered or are altered (by replacement, recrystallization, etc.). When the organism was alive, the hollow spaces probably contained soft tissue and liquids, but these have decayed way or drained out, thus leaving hollow spaces.

Petrifaction

Sometimes called Petrification usually means both replacement and permineralization combined in one specimen. Thus, in petrified wood the original cellulose has been replaced, and hollow spaces (of the wood's grain) have been permineralized. (Greek: petra = "rock")

Recrystallization

The structure of minerals within the body's original organic substances are changed into new, more stable forms. This can be recognized in a fossil by the appearance of flat, smooth, shiny crystal surfaces that can easily be seen and which reflect light. Also, permineralization may or may not fill in the hollow spaces of the recrystallized fossil.

Amber/Copal

When the outside of a tree is wounded, the tree will produce a soft sticky substance called resin to cover the wound as a natural "bandage". Resin is not tree sap, which is the liquid that transport nutrients throughout a tree (analogous to our blood). When resin becomes somewhat hardened it is called copal, and when it is fully hardened it is called amber. Because resin is something produced by a tree but not actually part of the tree's body, copal and amber may be considered product trace fossils of a tree. If a passing insect is entrapped by resin which hardens to copal or amber, then the insect is a body fossil within the amber/copal.

TRACE FOSSIL PRESERVATION

Behavior Trace Fossils

Tracks & Trails

Fossilized footprints and trails, whether single or multiple in extended trackways, document the locomotory behavior (crawling, walking, running, etc.) of animals, from dinosaurs to scorpions. The traces themselves are either natural molds of the bottom of the feet, or natural casts made by the filling in of the mold by overlying sediment. Even the impressions left by a resting animal can be preserved in sediments that later lithify. (See #19 and #20 below for more on impressions/molds and casts.)

Burrows

The soil or sediments surrounding an animal's underground burrow may lithify without the burrow (hollow space) being crushed or filled in. The resulting trace fossil is a hollow space or mold in the rock that represents burrow digging behavior. However, if the burrow is filled in with sediments that later lithify into sedimentary rock, then the result will be a rocky cast of the borrow showing the size and shape of the previously hollow burrow.

Dwellings

Underground animal dens or colonies may be preserved in the two different ways mentioned above for burrows. Also, above ground nest and hives may be preserved by one or more of the altered preservation processes mentioned above (e.g., replacement, permineralization, etc.

Feeding Indications

If a prey organism's body fossil is preserved with marks made by the feeding activity of its predator, then the marks are trace fossils of the predator's behavior. Also, lithified sediments can record the foraging marks made by bottom feeding animals that scoop up and filter sediment from the ocean floor.
Product Trace Fossils

Coprolites

When an animal excretes feces, this waste material usually just decays away. However, if the feces are buried and the waste material is replaced with minerals, then the hard fossilized feces are called coprolites. A similar thing can happen to regurgitated pellets of undigested bone and hair, although the term coprolite does not refer to them.

Gastroliths

If an animal swallows stones in its environment to aid in the digestion of food, then these gastroliths become rounded and smooth due to the grinding action of the muscular gizzard, a region of the digestive tract between the esophagus and the stomach. Gastroliths are clearly identifiable when preserved within the rib cage of an animal. Apparently, however, animals sometimes puked up a collection of gastroliths after they became worn and too small and smooth to be effective in grinding, and thus they are sometimes found away from a skeleton.

Eggs

Fossilized eggs are made by a female organism and (usually) laid outside of the body. They are therefore product trace fossils of the adult female, and generally only the egg shell is preserved. However, if a fossilized egg contains a fossilized embryo inside, then the embryo itself (probably preserved by replacement) is a body fossil.

Somatic Trace Fossils

Mold

If a dead body is buried and the surrounding sediments lithify into sedimentary rock, and then the body decays away, an empty space surrounded by rock will result. The walls of the space will be a mold in the rock of the external surface of the body. Thus a mold is a trace fossil, but neither a product of a body nor an indication of behavior. A mold may replicate either external (outside) or internal (inside) surfaces of a body. An everyday analogy for a mold is the decoratively shaped metal or plastic container into which hot liquid Jello is poured. When cooled to a jiggly solid and removed from the container, the outside surface of the Jello will have the shape of the inside surface of the

container. The container is thus a kind of mold, and the solid Jello is a cast (see below) of the mold. A relatively flat fossil mold is called an impression (similar to but not the same as compression - see #5 above.)

Cast

In the mold explanation above, if the empty space in the rock fills in with sediments or minerals, then the resulting fossil is a natural cast (= made by nature; artificial cast = made by humans) cast of the mold. Internal or external molds may produce internal or external casts. Casts may even be made by filling large hollow spaces within the body of an organism itself. Example: In a skull, the bony walls tightly surrounding the brain take on the shape of the outside surface of the brain. After death and burial, the brain rots away leaving an empty space (= brain cavity), which later fills in with sediments, which eventually lithify to sedimentary rock. Later still, the original (or fossilized) bone of the skull decays (or erodes) away, leaving only the sedimentary rock cast of the brain cavity. The cast replicates the size and external shape of the brain that used to fill the brain cavity. In this instance, the process by which this type of cast is made is like permineralization on a large scale. This type of cast is called a steinkern (STINE-kairn; German: “stone core”). Even in this case, however, no body parts are actually preserved.

A cast of the brain cavity, no matter how much it looks like a brain, is not the same as a true body fossil of the brain, in which the brain tissue itself is preserved by replacement, recrystallization, etc.

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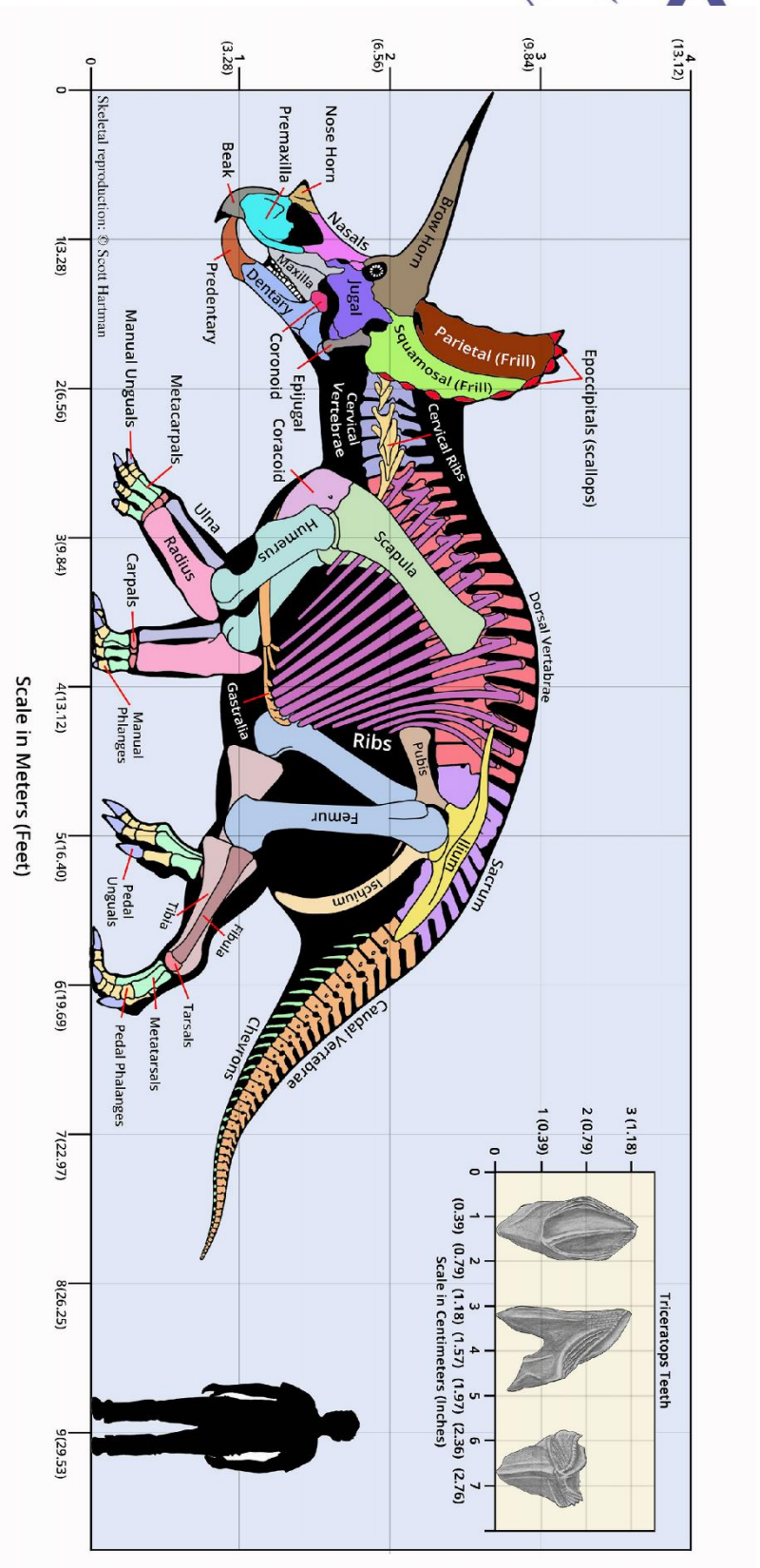
TRICERATOPS

Triceratops is a genus of herbivorous dinosaur that first appeared during the late Maastrichtian stage of the late Cretaceous period, about 68 million years ago (Mya) in what is now North America. It is one of the last known non-avian dinosaur genera, and became extinct in the Cretaceous–Paleogene extinction event 66 million years ago.[1] The term *Triceratops*, which literally means "three-horned face", is derived from the Greek τρί- (*tri-*) meaning "three", κέρας (*kéras*) meaning "horn", and ὤψ (*ops*) meaning "face".

Bearing a large bony frill and three horns on its large four-legged body, and possessing similarities with the modern rhinoceros, *Triceratops* is one of the most recognizable of all dinosaurs and the best known ceratopsid. It shared the landscape with and was probably preyed upon by the fearsome *Tyrannosaurus*, though it is less certain that the two did battle in the manner often depicted in traditional museum displays and popular images.

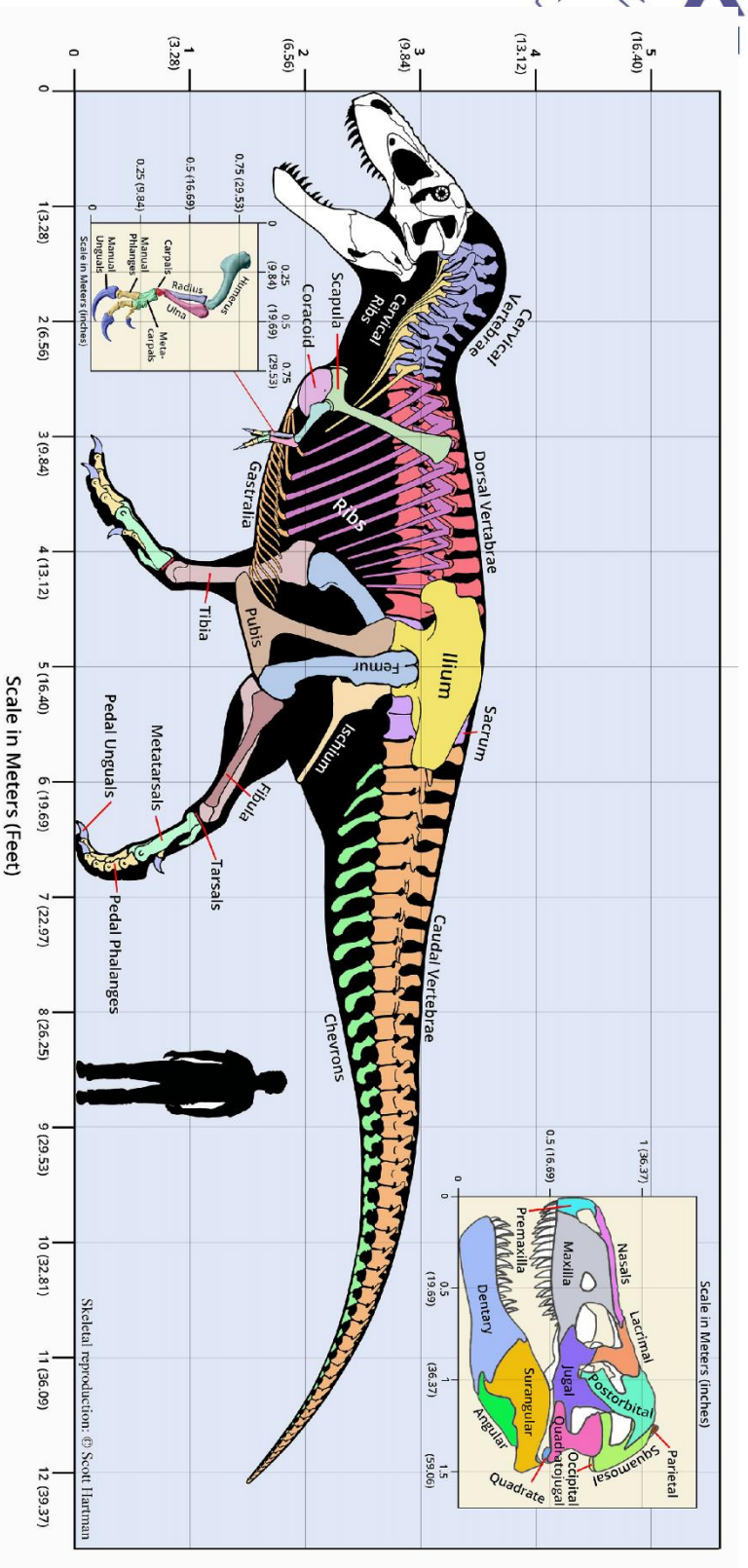
The exact placement of the *Triceratops* genus within the ceratopsid group has been debated by paleontologists. Two species, *T. horridus* and *T. prorsus*, are considered valid, although many other species have been named. Research published in 2010 suggested that the contemporaneous *Torosaurus*, a ceratopsid long regarded as a separate genus, represents *Triceratops* in its mature form. The view was immediately disputed and examination of more fossil evidence is expected to settle the debate.



TYRANNOSAURUS REX

Tyrannosaurus rex (meaning Tyrant Lizard King in Latin), commonly abbreviated to *T. rex*, is one of the most well-represented of the large theropods. *Tyrannosaurus* lived throughout what is now western North America. *Tyrannosaurus* had a much wider range than other tyrannosaurids. Fossils are found in a variety of rock formations datubg 68 to 66 million years ago. It was among the last non-avian dinosaurs to exist before the Cretaceous–Paleogene extinction event.

Like other tyrannosaurids, *Tyrannosaurus* was a bipedal carnivore with a massive skull balanced by a long, heavy tail. Relative to its large and powerful hind limbs, its fore limbs were short but unusually powerful for their size and had two clawed digits. The most complete specimen measures up to 12.3 m (40 ft) in length, up to 4 metres (13 ft) tall at the hips, and up to 6.8 metric tons (7.5 short tons) in weight. *T. rex* may have been an apex predator, preying upon hadrosaurs, ceratopsians, and possibly sauropods, although some experts have suggested the dinosaur was primarily a scavenger. The debate about whether *Tyrannosaurus* was an apex predator or scavenger was among the longest ongoing feud in paleontology; however, most scientists now agree that *Tyrannosaurus rex* was an opportunistic carnivore, acting as both a predator and a scavenger. it is estimated to be capable of exerting one of the largest bite forces among all terrestrial animals.



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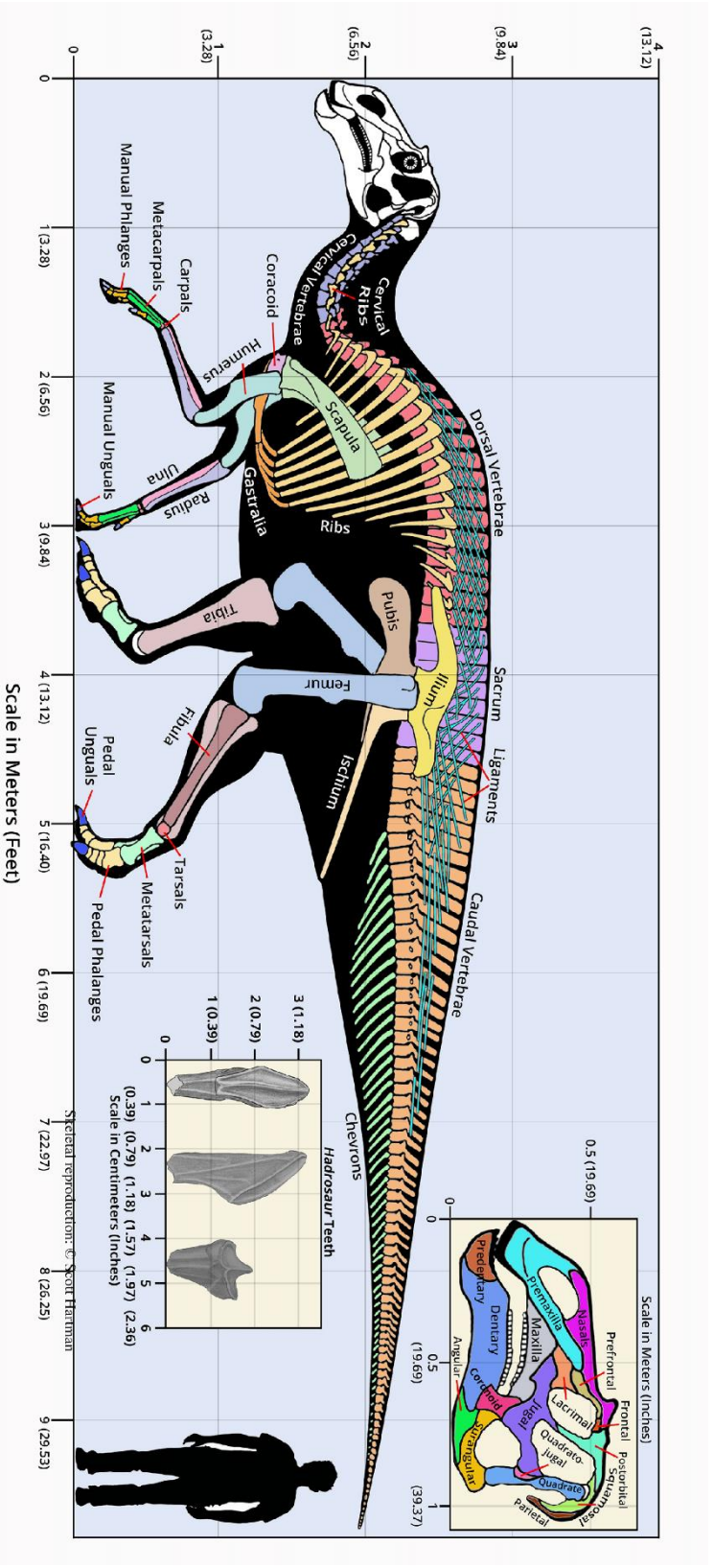
HADROSAURS

Also known as the duck-billed dinosaurs, for the flat, duck-bill appearance of the bones in their snouts. The family, which includes ornithopods such as *Edmontosaurus* and *Parasaurolophus*, was a common herbivore in the Upper Cretaceous Period of what is now Asia, Europe, Antarctica, South America, and North America.

Edmontosaurus is a genus of hadrosaurid dinosaur found in rocks of western North America that date from the late Campanian stage of the Cretaceous Period 73 million years ago. Edmontosaurus was one of the last non-avian dinosaurs, and lived alongside dinosaurs like Triceratops and Tyrannosaurus shortly before the Cretaceous–Paleogene extinction event.

Edmontosaurus was widely distributed across western North America. The distribution of *Edmontosaurus* fossils suggests that it preferred coasts and coastal plains. It was a herbivore that could move on both two legs and four. Because it is known from several bone beds, *Edmontosaurus* is thought to have lived in groups, and may have been migratory as well. The wealth of fossils has allowed researchers to study its paleobiology in detail, including its brain, how it may have fed, and its injuries and pathologies, nesting behaviors, such as evidence for a tyrannosaur attack on one edmontosaur specimen.



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Bureau of Land Management
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Fossil Excavation and Preparation
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