MOR TO LEARN

DINOSAURS
UNDER THE
BIG SKY

Educator’s Exhibit Guide
Grades 3-5

MOR aligns its programs with Montana Content Standards and Model Curriculum Guides.
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Dear Educators,

Welcome to Museum of the Rockies’ *Dinosaurs Under the Big Sky* Educator Guide!

Museum of the Rockies is a world-renowned dinosaur research facility with one of the largest and most important collections of dinosaur fossils in the world. The *Dinosaurs Under the Big Sky* exhibition has drawn millions of visitors from Montana and across the globe, including 15,000 students and teachers annually. Notable displays in this exhibition include the growth and behavior series of *Triceratops* and Montana’s *T. Rex*.

This guide from Museum of the Rockies contains a variety of worksheet-based activities that will invite your students to discover the world of dinosaurs — how they grew, ate, lived, and died. The science of paleontology explores and studies these processes and students will learn to draw evidence-based conclusions from the layers of the earth, insides of fossil bones, and comparisons with species — such as birds — that exist today.

Each student activity is accompanied by teacher resource pages that gives further context to the topic at hand and outlines how the activity should be structured. Aspects of the curriculum for third, fourth, and fifth grades, including Common Core and Next Generation Science Standards, are covered in each activity and outlined in the teacher resource pages. Please note that the standards listed with activities will not necessarily be met by completing student pages alone. The listed standards do take into account opportunities for extension activities.

This guide provides an ideal introduction to the Museum of the Rockies’ landmark collection of fossils and was made possible, in part, by a grant from the Institute of Museum and Library Services (IMLS). Welcome to the *Dinosaur Under the Big Sky* exhibit at Museum of the Rockies!

Sincerely,

Museum of the Rockies
HOW TO USE THIS GUIDE

The *Dinosaurs Under the Big Sky* Educator’s Guide is designed to be adaptable for the various learning opportunities found in Montana’s classrooms and informal learning environments. To make the most of this Educator’s Guide, select a theme to focus on with your students, identify the standards your selected activities address, then implement these activities in the classroom or at the Museum of the Rockies.

SELECT A THEME TO UNIFY ACTIVITIES

- To select which of the 15 activities will be best for your students, chose one of five themes based on your students’ grade level and curriculum.
- These themes are described on p. 6. Use the provided table to identify the activities that correspond to each theme. Activities are numbered consistently throughout this guide.
- Themes are indicated with icons throughout this guide.

CONNECT ACTIVITIES TO STANDARDS

- Identify how each activity addresses content standards by using the tables on pages 8-14.

USE THE ACTIVITIES...

IN THE CLASSROOM

This guide can be used in a classroom as an introduction for the exhibition before a field trip, or as a post-visit activity after a visit to Museum of the Rockies.

- If you are visiting MOR on a field trip, consider using these activities as pre- or post-visit lessons.
- Rent one of MOR’s Outreach Kits and use hands-on materials from our teaching collections to bring this world-class exhibit to your classroom. Outreach Kits that apply to each activity are listed in the Teacher’s Section of each activity.
- These activities can also be used in the classroom without any additional materials.
- Each activity has a student page to copy for each of your students, along with a section for teachers with background information and instructions.

IN THE MUSEUM

These activities can also be completed within the Museum during a field trip to engage students in learning during self-guided tours.

- Print copies of student pages and bring them with you on your visit to MOR.
- Use the exhibit map in this guide to identify where to complete each activity (identified by activity number). In the Teacher’s Section of each activity, MOR provides instructions on how to use these activities in the Museum.
This Educator’s Guide can be used in multiple ways. Explore one display in the *Dinosaurs Under the Big Sky* exhibit, or connect multiple areas using one of these five themes. These themes can be used to explore concepts within the exhibit space, or using hands-on materials available in MOR’s Outreach Kits.

**Practices of Science**

*Dinosaurs Under the Big Sky* engages students in the science of paleontology: how we know what we think we know about dinosaurs. Students encounter the latest research on life in the Mesozoic Era, abundantly evident in Montana, as well as the eight practices of scientific research.

**Grades 3-5** Students can use this exhibit as a real-life example of how the practices of science help us investigate, model, and explain the world. While all activities can support the practices of science, only key activities are highlighted.

**Structure, Function, and Adaptations (Life Science)**

Dinosaurs, like all animals, had internal and external structures that function to support survival, growth, behavior, and reproduction. *Dinosaurs Under the Big Sky* uses physical evidence to describe how these animals responded to changes in their environments.

**Grade 3** Students can investigate how characteristics impact an animal’s survival in different environments. Third grade can also explore biological evolution, including how fossils provide evidence of past life.

**Grade 4** Students can explore the different adaptations (internal and external structures) that support survival, growth, and behavior.

**Environments and Ecosystems (Life Science)**

Dinosaurs lived with many plants, animals, and decomposers. Dinosaurs interacted with each other and other organisms in their environment, creating a complex ecosystem. Changes in the environment impact all organisms in an ecosystem.

**Grade 3** Students can explore how some dinosaurs formed groups that helped their members survive.

**Grade 5** Students can explore relationships in ecosystems and food webs.

**Rocks and Minerals (Earth and Space Science)**

*Dinosaurs Under the Big Sky* highlights the various dinosaurs that lived in different times and places in Montana. Students explore how fossils found in different layers of rocks, called formations, can tell us how the landscape, in what is now Montana, has changed over time.

**Grade 4** Students can explore rock formations and fossils that provide evidence for how landscapes change over time.

**Grade 5** Students can explore the fossil evidence for how the Western Interior Seaway impacted on Montana’s landscape and animals.
Earth Systems (Earth and Space Science)

* Dinosaurs Under the Big Sky explores the area of the Earth during the Mesozoic Era that is now Montana. Montana’s climate, landforms, oceans, and rivers impacted the types of plants and animals that called this area home and the rock formations that were created.

**Grade 4** Students can explore how the Earth’s landscape changed over time and describe patterns of Earth’s features based on evidence in the fossil record.

**Grade 5** Students can explore ways the geosphere, biosphere, hydrosphere, and atmosphere interact and the distribution of Earth’s water using the fossil record.

### ACTIVITY PLANNER

Use this table to identify activities that support your students’ exploration of a theme.

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<th>Environments and Ecosystems</th>
<th>Rocks and Minerals</th>
<th>Earth Systems</th>
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<td>2. Practices of Paleontology</td>
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<tr>
<td>3. A Changing Landscape</td>
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<td>4. Once Upon a Time</td>
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<tr>
<td>5. Dinosaur... or Not?</td>
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<tr>
<td>6. Sort-A-Saurus</td>
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<td>7. How Big?</td>
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<td>8. What’s for Dinner?</td>
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<tr>
<td>9. Maiasaura</td>
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<tr>
<td>10. Triceratops Growth</td>
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<tr>
<td>11. Relative vs. Absolute Dating</td>
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<tr>
<td>12. Fossils in Your Backyard</td>
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<tr>
<td>13. Histology</td>
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<tr>
<td>14. People of Paleontology</td>
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</tbody>
</table>
Content Standards

The *Dinosaurs Under the Big Sky Educator’s Guide* is designed to be used for third, fourth, and fifth grade students. With activities for both the classroom and the museum setting, these fourteen lessons support teachers in interpreting the Museum of the Rockies’ *Dinosaurs Under the Big Sky* exhibit.

The following pages outline how these fourteen lessons connect to Montana Content Standards for third, fourth, and fifth grade students. We encourage teachers to use these tables to align these lessons to classroom curriculum.

While this guide is written for third, fourth, and fifth grade students, it can be adapted to students of all grades. Montana’s science standards and the Next Generation Science Standards (NGSS) follow similar forms with a great deal of overlap. Montana adds thoughtful integration of Montana’s Indian Education for All throughout the science standards. Because of their similarities, Museum of the Rockies uses Montana Science Standards and model curriculum while encouraging teachers from other states to use these guidelines to see how to integrate this curriculum into their classroom using NGSS.

Additionally, this curriculum supports Montana Content Standards for English Language Arts and Literacy, as well as Mathematics.
Montana Science Content Standards

3rd Grade

This curriculum guide addresses Montana Content Standards for Science, English Language Arts and Literacy, and Mathematics for students in grade 3.

This curriculum does not address any content standards for Physical Science for Grade 3.

<table>
<thead>
<tr>
<th>Montana Standard</th>
<th>Disciplinary Core Ideas (DCI’s)</th>
<th>Science and Engineering Practices (SEP’s)</th>
<th>Crosscutting Concepts (CCC’s)</th>
<th>Related Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtain and combine information to describe climate patterns in different regions of the world</td>
<td>ESS2.D</td>
<td>Constructing explanations and designing solutions</td>
<td>Stability and Change</td>
<td>1</td>
</tr>
<tr>
<td>Make a claim based on information about the merit of a design solution that reduces the impacts of a weather-related hazard</td>
<td>ESS3.B</td>
<td>Engaging in argument from evidence</td>
<td>Cause and Effect</td>
<td>5</td>
</tr>
</tbody>
</table>
## Grade 3 Life Science

<table>
<thead>
<tr>
<th>Montana Standard: Students must know and be able to:</th>
<th>Disciplinary Core Ideas (DCI's)</th>
<th>Science and Engineering Practices (SEP's)</th>
<th>Crosscutting Concepts (CCC's)</th>
<th>Related Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all</td>
<td>LS4.C</td>
<td>Engaging in argument from evidence</td>
<td>Cause and effect</td>
<td>5, 7, 8, 9</td>
</tr>
<tr>
<td>Make a claim about the effectiveness of a solution to a problem caused when the environment changes and that the types of plants and animals that live there may change</td>
<td>LS2.C</td>
<td>Engaging in argument from evidence</td>
<td>System and System Models</td>
<td>3, 4, 5</td>
</tr>
<tr>
<td>Construct a cause and effect argument communicating some animals, including humans, form groups and communities that help members survive</td>
<td>LS2.D</td>
<td>Engaging in argument from evidence</td>
<td>Cause and effect</td>
<td>5, 7, 8, 9, 13</td>
</tr>
<tr>
<td>Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago</td>
<td>LS4.A</td>
<td>Analyze and Interpret data</td>
<td>Scale proportion and quantity</td>
<td>1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13</td>
</tr>
<tr>
<td>Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death</td>
<td>LS1.B</td>
<td>Developing and Using Models</td>
<td>Patterns</td>
<td>9, 10, 13</td>
</tr>
<tr>
<td>Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms</td>
<td>LS3.A</td>
<td>Analyze and Interpret data</td>
<td>Patterns</td>
<td>5, 6, 7, 8, 9, 10</td>
</tr>
<tr>
<td>Use evidence to support the explanation that traits can be influenced by the environment</td>
<td>LS3.A &amp; LS3.B</td>
<td>Construct explanations and Design Solutions</td>
<td>Cause and effect</td>
<td>5, 6, 7</td>
</tr>
<tr>
<td>Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing</td>
<td>LS4.B</td>
<td>Construct explanations and Design Solutions</td>
<td>Cause and effect</td>
<td>7, 9, 10</td>
</tr>
</tbody>
</table>
Montana Science Content Standards

4th Grade

This curriculum guide addresses Montana Content Standards for Science, English Language Arts and Literacy, and Mathematics for students in grade 4.

This curriculum does not address any content standards for Physical Science for Grade 4.

### Grade 4 Earth and Space Science

<table>
<thead>
<tr>
<th>Montana Standard</th>
<th>Disciplinary Core Ideas (DCI’s)</th>
<th>Science and Engineering Practices (SEP’s)</th>
<th>Crosscutting Concepts (CCC’s)</th>
<th>Related Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time</td>
<td>ESS1.C</td>
<td>Construct explanations and Design Solutions</td>
<td>Patterns</td>
<td>1, 3, 4, 5, 11, 12</td>
</tr>
<tr>
<td>Make observations or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation</td>
<td>ESS2.A</td>
<td>Planning and carrying out investigations</td>
<td>Cause and effect</td>
<td>1</td>
</tr>
<tr>
<td>Analyze and interpret data from maps as evidence to make a claim about patterns of Earth’s features</td>
<td>ESS2.B</td>
<td>Analyze and Interpret data</td>
<td>Patterns</td>
<td>3, 12</td>
</tr>
</tbody>
</table>

### Grade 4 Life Science

<table>
<thead>
<tr>
<th>Montana Standard</th>
<th>Disciplinary Core Ideas (DCI’s)</th>
<th>Science and Engineering Practices (SEP’s)</th>
<th>Crosscutting Concepts (CCC’s)</th>
<th>Related Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction</td>
<td>LS1.A</td>
<td>Engaging in argument from evidence</td>
<td>System and System Models</td>
<td>5, 6, 7, 8, 9, 10, 13</td>
</tr>
</tbody>
</table>
Montana Science Content Standards

5th Grade

This curriculum guide addresses Montana Content Standards for Science, English Language Arts and Literacy, and Mathematics for students in grade 5.

### Grade 5 Earth and Space Science

<table>
<thead>
<tr>
<th>Montana Standard</th>
<th>Disciplinary Core Ideas (DCI’s)</th>
<th>Science and Engineering Practices (SEP’s)</th>
<th>Crosscutting Concepts (CCC’s)</th>
<th>Related Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, or atmosphere interact</td>
<td>ESS2.A</td>
<td>Developing and Using Models</td>
<td>System and System Models</td>
<td>1, 3, 8</td>
</tr>
<tr>
<td>Obtain and combine information from various sources about ways individual communities use science ideas to protect the Earth's resources, environment, and systems and describe examples of how American Indians use scientific knowledge and practices to maintain relationships with the natural world</td>
<td>ESS3.C</td>
<td>Obtaining, Evaluating, &amp; Communicating Information</td>
<td>System and System Models</td>
<td>2, 12</td>
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### Grade 5 Life Science

<table>
<thead>
<tr>
<th>Montana Standard</th>
<th>Disciplinary Core Ideas (DCI’s)</th>
<th>Science and Engineering Practices (SEP’s)</th>
<th>Crosscutting Concepts (CCC’s)</th>
<th>Related Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop and critique a model to describe the movement of matter among plants, animals, decomposers, and the environment</td>
<td>LS2.A</td>
<td>Developing and Using Models</td>
<td>System and System Models</td>
<td>7, 8</td>
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### Grade 5 Physical Science

<table>
<thead>
<tr>
<th>Montana Standard</th>
<th>Disciplinary Core Ideas (DCI’s)</th>
<th>Science and Engineering Practices (SEP’s)</th>
<th>Crosscutting Concepts (CCC’s)</th>
<th>Related Activity</th>
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<tbody>
<tr>
<td>Use models to describe that energy in animals' food was once energy from the sun</td>
<td>PS3.D</td>
<td>Developing and Using Models</td>
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Montana Content Standards For English Language Arts And Literacy
3rd, 4th, and 5th Grade

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<td>Knowledge of Language</td>
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Montana Content Standards For Math

3rd, 4th, and 5th Grade

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<td>3, 4, 7</td>
<td>3, 4, 7</td>
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Exhibit Overview

Museum of the Rockies (MOR) was founded in 1957 by Dr. Caroline McGill. She worked with Montana State University’s then president, Dr. Roland R. Renne and Dr. Merril Burlingame, head of the History Department to establish the Museum. In the years since, the Museum has moved from its original home in a set of Quonset huts to the building where it is today. In 1982, MOR Director Mick Hager hired Jack Horner as the Curator of Paleontology.

For the next thirty years, Horner and the Museum’s paleontology staff established MOR as a world-class paleontology research facility, and led field teams to expand the Museum’s collections to include over 35,000 specimens. MOR houses the largest collection of dinosaurs collected in the United States. MOR curators and staff, MSU faculty, and students in collaboration with research scientists from museums and academic institutions around the world conduct research on the paleontological collections housed at MOR.

_Dinosaurs Under the Big Sky_ showcases significant fossils from the MOR’s paleontology collection. Exhibits include landmark discoveries with some of the first dinosaur eggs discovered from North America, evidence of nesting colonies and parental care among dinosaurs, dinosaur embryos, examples of soft tissue found in fossil bone, and the first discovery of a burrowing dinosaur.

The Hall of Horns and Teeth features Montana’s T. rex, one of only a few _Tyrannosaurus rex_ skeletons mounted with real bone. The most complete ontogenetic (growth) series of _Triceratops_ and _Tyrannosaurus rex_ skulls can only be seen at Museum of the Rockies.
Exhibit Overview (Cont.)

*Dinosaurs Under the Big Sky* covers approximately 90 million years of the Earth’s history interpreted through dinosaur remains discovered in Montana and the surrounding region. MOR’s professional paleontology technicians and trained volunteers, along with other Montana craftsmen, sculptors, and artists worked on the exhibition over a four-year period.

The exhibition begins with an introduction to the scientific process, the field of paleontology, the fossilization process, answers to common questions about dinosaurs, and where fossils are found. The Bowman Dinosaur Viewing Laboratory gives visitors the opportunity to observe MOR’s professionally trained fossil preparators at work cleaning and preparing fossils for research and/or exhibition purposes.
**Essential Background Information**

**Science Practices  I  How do we know what we think we know about dinosaurs?**

- Science advances as we learn more and modify our current understandings.
- Physical evidence is the most important clue scientists can use to learn about dinosaurs.
- In the science of paleontology, the physical evidence is fossils.
- Paleontologists observe and compare fossils from extinct life to learn new information.
- A hypothesis is a scientific idea supported by physical evidence.
- Scientists come up with hypotheses based on what they think the fossils are telling them.
  Then they try to find ways to test those hypotheses and falsify their hypotheses by using physical evidence.
- If after exhaustive testing a hypothesis has not been falsified, it can be called a scientific theory.
- The Theory of Gravity is an example of a scientific theory that has not yet been falsified.

**Scientific and Engineering Practices from the Montana State Science Standards**
What is a dinosaur?

- A group of reptiles that lived 230-66 million years ago during the Mesozoic Era.
- The only reptiles to walk with their legs right under their bodies, not sprawled to the sides.
- Scientists have found many lines of evidence supporting the idea that birds evolved from dinosaurs.
- Dinosaurs that lived in the past and that are extinct are called non-avian dinosaurs and dinosaurs that live now are called avian dinosaurs, or birds.
- In *Dinosaurs Under the Big Sky*, we focus on non-avian extinct dinosaurs, but we will look at evidence that supports the idea that birds are dinosaurs.
- There are many extinct animals that are not dinosaurs—woolly mammoth, saber-toothed tiger, *Dimetrodon*, swimming reptiles, flying reptiles.
- Humans lived long after the dinosaurs—humans and non-avian dinosaurs never lived at the same time.

Different dinosaurs, different times, different places in Montana.

- The Mesozoic Era (the time when non-avian dinosaurs lived) is divided into three parts—the Triassic, Jurassic and Cretaceous periods.
- *Dinosaurs Under the Big Sky* focuses on the Late Jurassic through the end of the Cretaceous period—about 90 million years of that time.
- Different dinosaurs lived in different times and places in Montana—we find their fossils in different layers of rocks, called formations.
- In *Dinosaurs Under the Big Sky*, you will see what kinds of dinosaurs lived together at different times in Montana.
- Scientists also find fossil evidence of plants and other animals in each formation—this helps them piece together what each environment might have been like.
How do we know where to find dinosaurs?

- Geologists (scientists who study Earth’s processes) make maps that show where different age and types of rocks are exposed at the Earth’s surface.
- Paleontologists look on geologic maps to find areas where the right age and type of rocks are exposed.
- They get permission to “prospect” in those areas for dinosaur bones.
- In *Dinosaurs Under the Big Sky*, you will visit areas that show what kinds of dinosaurs were found in different rock formations of different ages.
Geologic Map of Montana

EXPLANATION

- CENOZOIC
- MESOZOIC
- PALEOZOIC
- PROTEROZOIC
- ARCHEOZOIC
- IGNEOUS

GENERALIZED GEOLOGIC MAP OF MONTANA

Used with permission from the Montana Bureau of Mines and Geology
HALL OF GIANTS
VIEWING LAB
HALL OF GROWTH & BEHAVIOR
MESOZOIC MEDIA CENTER
HALL OF HORNS & TEETH: Part 1
HALL OF HORNS & TEETH: Part 2

DINOSAURS under the BIG SKY
Siebel Dinosaur Complex

ACTIVITY LOCATIONS
Making a Fossil
Activity Overview

BIG IDEA
Not every organism that died, including dinosaurs, left behind a fossil. Explore fossilization with this activity.

OBJECTIVE
Students will follow a series of steps outlining the events needed for fossil formation and understand that this process takes place over a long period of time.

BACKGROUND
A fossil is evidence of past life. This activity describes bone fossils. Other types of fossils, like dinosaur footprints, or trace fossils, have a similar process of fossilization. Share these basic steps of fossilization with your students to complete this activity.

Step 1: Death
Dinosaurs that die near water or in a windy area have a greater chance of becoming a fossil because water and wind carry sand and mud which can bury the dinosaur.

Step 2: Burial
The river’s current pushes sand and mud over the dinosaur’s body, completely covering it. The burial step is one of the most important steps, because it allows the dinosaur’s body to be preserved and protects its remains from scavengers. Frequently, paleontologists find incomplete fossilized skeletons. Ask students if they have any ideas why fossilized skeletons may be incomplete. Sometimes the dinosaur’s remains are scattered by scavengers, predators, or water currents before burial occurs.
Making a Fossil
Activity Overview (Cont.)

**Step 3: Permineralization**
Minerals from the surrounding sand, mud, and water fill into cell spaces within the bones of the dinosaur. If available have students examine a bone or fossilized bone and notice the tiny holes in the bones. Explain that in living animals’ bones (including their bones), blood vessels travel through these tiny tunnels, nourishing the bone and allowing it to strengthen and grow. When the animal dies, the blood vessels deteriorate leaving the holes behind. These holes are what allow the bones to absorb the surrounding minerals. To assess student understanding of permineralization, take a class survey, “What are fossils? Bones or rocks?” Fossils are rocks; as permineralization occurs the bone is slowly replaced with minerals, and minerals are the ingredients of rocks.

**Step 4: Time passes**
In order for the fossil to last for millions of years, it must stay completely covered. Even though rocks are stronger than bones, with time and exposure to weather, they can still erode and disintegrate.

**Step 5: Uplift and Erosion**
The layers of our Earth are constantly in motion! In order for the fossil to be discovered, the layer in which the fossil is buried must be pushed closer to the surface, or the layers covering it must be worn away.

**Step 6: Discovery**
When a fossil is discovered, it is important that it is left where it is so that a paleontologist can study it. The location of the fossil and other rocks and fossils around it are just as important as the fossil itself!
Making a Fossil
Activity Overview Cont.

BACKGROUND (CONT.)

Have We Found All the Dinosaurs?
Wang & Dodson (2006) used a statistical method, the abundance-based coverage estimator (ACE), to calculate the number of genera of dinosaurs that may have existed in the Mesozoic Era. This statistical analysis only identifies those genera that have "discoverable" fossils. A genus that left no fossils at all can never be discovered, and cannot be counted by ACE or any similar statistical method based only on abundance counts.

Not all types of dinosaurs will be found in the fossil record. Some genera may have never become fossils. These dinosaurs may not have died in an environment that had the right conditions for fossilization. It is also possible that some genera were fossilized, but lost over time due to mountain building processes.

According to Wang & Dodson (2006), only 29% of “discoverable” dinosaur genera have been identified. These scientists estimate that new dinosaurs will continue to be discovered for at least another century. However, it is likely that not every dinosaur genera is recorded in the fossil record and our understanding of dinosaurs is incomplete based on the accessibility of the fossiliferous rock studied at the Earth’s surface. Even though rocks are stronger than bones, with time and exposure to weather, they can still erode and disintegrate.

EXTENSIONS

• Use the MOR Outreach Kit: Fossils, to explore the different types of fossils.

• Complete the Process of Paleontology activity in this guide to learn how scientists discover, excavate, and prepare fossils for display or research.

• Visit Museum of the Rockies on a field trip to see real fossils on display.
MAKING A FOSSIL
Museum Instructions

MATERIALS
Student activity sheets, clipboards, pencils (Pens, crayons, and markers are not allowed in exhibit spaces)

LOCATION
This activity can be used as an introduction to the Dinosaurs Under the Big Sky exhibit, providing students with a basic understanding and appreciation of how the fossils on display formed.

Tell the students that as they explore the Dinosaurs Under the Big Sky exhibit, they will be seeing hundreds of real fossils. Today, they will explore how fossils are formed.

Use the space in front of the Viewing Lab to seat students and read the steps of fossilization (found in the Background Information) to your students. Use the replica of sedimentary rock layers along the wall by the Lab and the fossils embedded in rock on display, to provide visuals for the various steps of fossilization.

Using the activity sheet, instruct your students to draw or write the six basic steps in boxes provided.
MAKING A FOSSIL
Museum Instructions (Cont.)

Walk into the first portion of the Dinosaur Halls – the Hall of Growth and Behavior. Ask students to look at the graphic panels behind the displays and the displays. Ask, what kind of climate did the dinosaurs now found in Montana live in? Students should describe a climate that is moisture-rich, that supported the plants some dinosaurs ate. This climate also supported the rivers, streams, and inland sea that provided sediment to bury some dinosaurs after their death. This was a time of deposition.

Walk into the Mesozoic Media Center – the portion of the Dinosaur Halls with monitors and videos. When the video loop shows eastern Montana, ask your students what kind of climate is best for revealing and discovering fossils? Students should describe an arid climate where erosion and weathering uncover fossils. While paleontologists worldwide can find dinosaurs in other climates, the arid environment of eastern Montana helps fossil discovery by making fossils easier to find on the earth’s surface.

Continue your exploration and stop in the Hall of Horns and Teeth, where Montana’s T.rex is on display. Ask students to hypothesize the completeness of the fossil record. If 100 dinosaurs lived in your town in Montana 66 million years ago, how many of them have scientists found today? This portion of the Dinosaur Halls can be misleading when asking this question. While MOR displays multiple growth series and hundreds of real fossils, fossilization is actually rare. Use this discussion to explore how many fossils have been found and how many more scientists expect to find in the next 100 years.

Share with your students that Montana is incredibly special because scientists are able to find dinosaur fossils here. Fossilization is rare! Museum of the Rockies houses hundreds of very special fossils that help us better understand the Earth millions of years ago.
MAKING A FOSSIL
Classroom Instructions

MATERIALS
Sheets of felt (5-6 pieces); dinosaur or animal toy; images of eastern Montana MOR Outreach Kit: Fossils

ACTIVITY TIME
45 Minutes

INSTRUCTIONS
This activity can be used as a pre-lesson to a visit to Museum of the Rockies, where hundreds of real fossils are on display.

Introduce the activity by asking students what they know about fossils. Record student answers on a whiteboard or poster paper. Revisit the list they come up with after completing the activity.

Tell the students that they will be exploring how organisms, specifically the bones of dinosaurs, become fossils.

Read the steps of fossilization (found in the Background Information) to your students. Use felt and a plastic dinosaur, along with photos of eastern Montana, to provide a visual demonstration of fossilization while describing these steps. Alternatively, have your students read this description (printable handout in the Appendix).

Using the activity sheet, instruct your students to draw or write the six basic steps in boxes provided.

Ask your students to look at the first two steps of fossilization – death and burial. Ask, when dinosaurs lived in the area that is now Montana, what kind of climate existed? Students should describe a climate that is moisture-rich, that supported the plants some dinosaurs ate. This climate also supported the rivers, streams, and inland sea that provided sediment to bury some dinosaurs after their death. This was a time of deposition.
MAKING A FOSSIL
Classroom Instructions (Cont.)

Now have your students look at the final two steps of fossilization – uplift, erosion, and discovery. Think about eastern Montana today. Ask, what kind of climate is best for revealing and discovering fossils? Students should describe an arid climate where erosion and weathering uncover fossils. While paleontologists worldwide can find dinosaurs in other climates, the arid environment of eastern Montana helps fossil discovery by making fossils easier to find on the earth’s surface.

After exploring the process of fossilization and climate, ask students to hypothesize the completeness of the fossil record. If 100 dinosaurs lived in your town in Montana 66 million years ago, how many of them have scientists found today? Use this discussion to explore how many fossils have been found and how many more scientists expect to find in the next 100 years.

Share with your students that Montana is incredibly special because scientists are able to find dinosaur fossils here. Fossilization is rare! If available, conclude this activity by sharing a real fossil with your students and/or revisiting the list of what students know about fossils.
Making a Fossil

Read or listen to the story of fossilization. Recount the key details of how fossils form.

Draw or write the steps below.

Step 1: _______________________

Step 2: _______________________

Step 3: _______________________

Step 4: _______________________

Step 5: _______________________

Step 6: _______________________
Weather and Climate

Weather and climate affect fossilization.

What type of climate do you think erodes rocks and reveals fossils? Why?

In the Mesozoic Media Center, or using images in your classroom, look at images or videos of eastern Montana where we find dinosaur fossils. Based on the weather and climate of this region, why is Montana a great place to find dinosaurs?

Have we found all the dinosaurs?

Scientists estimate that there may have been close to 1,850 genera or groups of dinosaurs. Currently, only 527 genera have been discovered.*

Calculate how many types of dinosaurs scientists think we know about today based on this ratio. 527 in 1,850

As a decimal: __________________________________________________________

As a percentage: _______________________________________________________

Do you think scientists will uncover all the different types of dinosaurs that ever lived? Why or why not?

Activity 1: Student Handout

Story of fossilization

**Step 1: Death**
Dinosaurs that die near water or in a windy area have a greater chance of becoming a fossil because water and wind carry sand and mud which can bury the dinosaur.

**Step 2: Burial**
The river’s current pushes sand and mud over the dinosaur’s body, completely covering it. The burial step is one of the most important steps, because it allows the dinosaur’s body to be preserved and protects its remains from scavengers. Frequently, paleontologists find incomplete fossilized skeletons. Ask students if they have any ideas why fossilized skeletons may be incomplete. Sometimes the dinosaur’s remains are scattered by scavengers, predators, or water currents before burial occurs.

**Step 3: Permineralization**
Minerals from the surrounding sand, mud, and water soak into the bones of the dinosaur. If available have students examine a bone or fossilized bone and notice the tiny holes in the bones. Explain that in living animals’ bones (including their bones), blood vessels travel through these tiny tunnels, nourishing the bone and allowing it to strengthen and grow. When the animal dies, the blood vessels deteriorate leaving the holes behind. These holes are what allow the bones to absorb the surrounding minerals. To assess student understanding of permineralization, take a class survey, “What are fossils? Bones or rocks?” Fossils are rocks; as permineralization occurs the bone is slowly replaced with minerals, and minerals are the ingredients of rocks.

**Step 4: Time passes**
In order for the fossil to last for millions of years, it must stay completely covered. With time and exposure to weather, fossils can erode and disintegrate.
Activity 1
Story of fossilization (Cont.)

Step 5: Uplift and Erosion
The layers of our Earth are constantly in motion! In order for the fossil to be discovered, the layer in which the fossil is buried must be pushed closer to the surface, or the layers covering it must be worn away.

Step 6: Discovery
When a fossil is discovered, it is important that it is left where it is so that a paleontologist can study it. The location of the fossil and other rocks and fossils around it are just as important as the fossil itself!
Making a Fossil

Read or listen to the story of fossilization. Recount the key details of how fossils form.

Draw or write the steps below.

Step 1: ___________  Step 2: ___________
DEATH           BURIAL

Step 3: ___________  Step 4: ___________
PERMINERALIZATION TIME PASSES

Step 5: ___________  Step 6: ___________
UPLIFT AND EROSION DISCOVERY
Weather and Climate

Weather and climate affect fossilization.

What type of climate do you think erodes rocks and reveals fossils? Why?

A dry and windy climate causes more erosion and can lead to exposed fossils.

In the Mesozoic Media Center, or using images in your classroom, look at images or videos of eastern Montana where we find dinosaur fossils. Based on the weather and climate of this region, why is Montana a great place to find dinosaurs?

Montana is a great place to find dinosaurs because it is dry or arid. Wind and rain causes sedimentary rocks to erode, sometimes revealing fossils.

Have we found all the dinosaurs?

Scientists estimate that there may have been close to 1,850 genera or groups of dinosaurs. Currently, only 527 genera have been discovered.*

Calculate how many types of dinosaurs scientists think we know about today based on this ratio. 527 in 1,850

As a decimal: 0.285

As a percentage: 28.5%

Do you think scientists will uncover all the different types of dinosaurs that ever lived? Why or why not?

No. It is possible that all types of dinosaurs were not fossilized.

Eastern Montana is a great place to find dinosaurs.
Many specific steps and techniques are followed and used between asking permission and discovering a fossil to museum research and display. These steps make up the practices of paleontology.

Students will explore the major steps in the practices of paleontology and learn about how this practice varies based on the different fossils on display at Museum of the Rockies.

In order to find fossils, you first need to know where to look. For example, if you want to find a *Tyrannosaurus rex* you will need to find rocks that were deposited at the time that *T.rex* lived. Geologists study the Earth and make detailed maps that show where different aged rocks are exposed at the Earth’s surface. By studying a geologic map, you may identify a promising location to look for a *T. rex*.

Before you can dig up a dinosaur, you next need to make sure you have permission to do so. Often you may need a special permit to excavate fossils.

Once you have obtained permission, you can then go out and look for fossils. This is called prospecting. When paleontologists are prospecting, they typically spend a lot of time hiking outdoors, searching the ground for pieces of fossils. If you’re prospecting, you may find a trail of fossil pieces leading you to something eroding out of a hillside – a discovery of a fossil. At this point, it may be difficult to determine what exactly is in the hill. It could be a fossil rib, or an entire skeleton. The only way to find out is to dig into the hill and begin excavating the fossil.

Paleontologists have to be very careful when they excavate a fossil, because they are often very fragile. Shovels, hammers, and picks may be used to remove rock but smaller brushes and chisels are used when working close to the fossil.
Once the fossils are exposed, they might be coated with glues or hardeners to help keep them together during the excavation. Before the specimens are removed from the ground, it is very important to record as much information as possible about how they are positioned in the rocks. This may help you to figure out how the fossil was preserved, or how the animal died. Paleontologists take detailed notes and photographs, measurements of depth and orientation, and draw maps of how the fossils are positioned in the ground.

Once all of this information is collected, it is time to carefully remove the fossils from the ground. To do this, paleontologists typically coat fossils in layers of burlap and plaster, creating a field jacket. A field jacket is similar to the cast a doctor might put around a broken arm; just as that cast is made to protect a broken bone, a field jacket is made to protect the fossil as it is transported from the field back to the museum. The size of a field jacket depends on what’s inside; sometimes a field jacket is very small and you can carry it out of the field in your hand; sometimes field jackets are so large and heavy that a helicopter is required to lift it and carry it to a truck for transport back to the museum.

Once back at the museum, the field jackets are opened and the remaining rock must be carefully removed from around the fossil. During preparation, scientists use picks and brushes to carefully remove the rock that has encased the fossil for millions of years. Sometimes, if the rock is very hard, they may need to use more powerful tools, such as an air scribe, which is like a small jack-hammer that chips away hard rock bit by bit. Preparators fit together any broken pieces of the fossil, so that it can be studied. Sometimes fossils can take weeks, months, or even years to prepare, depending on how fragmented they are and how hard the rock encasing them is.
Once the fossil is prepared, it goes into the museum’s fossil collections. The collections area is like a library, but instead of books, it contains fossils. Each specimen is assigned a number and entered into a computer database. This allows the museum to keep track of each fossil. The fossil is stored on a shelf or in a cabinet. Now that the fossil is cataloged, it can be available for research, education, or display in a museum exhibition.
These steps in the practices of paleontology can take different amounts of time for each specimen or project. Museum of the Rockies provides the following estimates on how long these steps took for four specimens on display. This data is only an estimate and should be used for educational purposes only.

<table>
<thead>
<tr>
<th></th>
<th>Wankel T.rex MOR 555</th>
<th>Torosaurus MOR 1122</th>
<th>Yoshi’s Trike MOR 3027</th>
<th>Thescelosaurus MOR 979</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permission</td>
<td>3 weeks</td>
<td>1 day</td>
<td>5 weeks</td>
<td>5 weeks</td>
</tr>
<tr>
<td>Discovery</td>
<td>1 day</td>
<td>1 day</td>
<td>1 day</td>
<td>1 day</td>
</tr>
<tr>
<td>Excavation</td>
<td>14 days (1989)</td>
<td>2 weeks + 25 days (1990)</td>
<td>2 weeks</td>
<td>6 weeks</td>
</tr>
<tr>
<td>Transportation</td>
<td>2 days</td>
<td>2 days</td>
<td>2 days</td>
<td>2 days</td>
</tr>
<tr>
<td>Preparation</td>
<td>2 years</td>
<td>4 weeks</td>
<td>6 months</td>
<td>3 years + (and counting!)</td>
</tr>
<tr>
<td>Display</td>
<td></td>
<td></td>
<td>9 months</td>
<td></td>
</tr>
</tbody>
</table>

**EXTENSIONS**

- Use the MOR Outreach Kit: Practices of Paleontology, to teach this process in more depth and facilitate a mock fossil preparation activity.
- Visit Museum of the Rockies on a field trip to see the real fossils described in this activity on display.
PRACTICES OF PALEONTOLOGY

Museum Instructions

MATERIALS
Student activity sheets, clipboards, pencils (Pens, crayons, and markers are not allowed in exhibit spaces)

LOCATION

ACTIVITY TIME
30 Minutes

INSTRUCTIONS
This activity can be used to explore the Dinosaurs Under the Big Sky exhibit to help students understand how the practices of science guide paleontologists in understanding dinosaurs and creating museum exhibitions.

Introduce the activity by asking students if anyone has thought about being a paleontologist for a career. We often think of paleontologists as scientists that study dinosaurs, but paleontologists can study any form of extinct life. Just like all scientists, paleontologists follow a series of steps, or scientific practices, to study fossils.

Tell the students that they will be exploring how paleontologists discover fossils and all the steps they follow to get a dinosaur on display, like those at Museum of the Rockies.

Before starting this activity, walk by the Viewing Lab and have students look at and identify the fossil jackets on display. This step in the practice of paleontology is best seen in this area of the Museum.

Sit students in the first hall, the Hall of Giants, near the “Muddy Grave” display. Tell the students that this display recreates how these dinosaur fossils were found.
PRACTICES OF PALEONTOLOGY
Museum Instructions (Cont.)

Read the practices of paleontology for the “Muddy Grave” (found in the Appendix) to your students. This specific story will help your students connect these practices with the display they see in front of them.

Using the activity sheet, instruct your students to draw or write the six basic steps in boxes provided. These steps are simplified from the full story the students read or listened to. Ask students to think about what could be described in more detail, or what is missing, from their pictures or descriptions, that they heard during the story.

Describe to your students that each fossil scientists find can take a different amount of time for each of these six simplified steps. Assign or distribute the descriptive sheets (available in the Appendix) estimating the practice of paleontology for four different dinosaur specimens on display at MOR. Have students find these specimens on display in the Dinosaur Halls and complete the table to describe this process for their specimen. If time allows, visit each of these displays as an entire group and have the students who studied the specimen share their findings. As a class, compare and contrast the specimens and debrief this activity by discussing why these four specimens were different. What factors affect the process of paleontology?

Conclude the lesson by emphasizing that like all fields of science, paleontology has a specific set of practices. Compare and contrast these practices to other areas of science that students have studied or are familiar with.
PRACTICES OF PALEONTOLOGY
Classroom Instructions

MATERIALS
- MOR “Practices of Paleontology” PowerPoint slides (or printed images of these slides);
- MOR Outreach Kit: Practices of Paleontology including example of field jacket, examples of a mold and cast, and sedimentary rock samples

ACTIVITY TIME
45 Minutes

INSTRUCTIONS
- This activity can be used as a pre-lesson to a visit to Museum of the Rockies, where hundreds of real fossils are on display showcasing the practices of paleontology.

Introduce the activity by asking students if anyone has thought about becoming a professional paleontologist. We often think of paleontologists as scientists that study dinosaurs, but paleontologists can study any form of extinct life. Just like all scientists, paleontologists follow a series of steps, or scientific practices, to study fossils.

Tell the students that they will be exploring how paleontologists discover fossils and all the steps they follow to get a dinosaur on display, like those at Museum of the Rockies.

Read the practices of paleontology (found in the Background Information) to your students. Use the PowerPoint presentation to provide a visual demonstration of fossilization while describing these steps. Alternatively, have your students read this description (printable handout in the Appendix). If possible, use the resources in the outreach kit to show real examples of a field jacket, preparation tools, a mold and cast, and fossils and rocks.

Using the activity sheet, instruct your students to draw or write the six basic steps in boxes provided. These steps are simplified from the full story the students read or listened to. Ask students to think about what could be described in more detail, or what is missing, from their pictures/descriptions, that they heard during the story.
INSTRUCTIONS (CONT.)

Describe to your students that each fossil scientists find can take a different amount of time for each of these six simplified steps. Assign or distribute the descriptive sheets (available in the Appendix) estimating the practice of paleontology for four different dinosaur specimens on display at MOR. Have students complete the table to describe this process for their specimen, then compare with another student. As a class, debrief this activity by discussing why these four specimens were different. What factors affect the process of paleontology?

Conclude the lesson by emphasizing that like all fields of science, paleontology has a specific set of practices. Compare and contrast these practices to other areas of science that students have studied or are familiar with.
Practices of Paleontology

Scientists, including paleontologists, follow specific steps to find fossils and prepare them for display or research. Recount the key details of the practices of paleontology. Draw or write the steps below.

<table>
<thead>
<tr>
<th>1: PERMISSION</th>
<th>2: DISCOVERY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3: EXCAVATION</th>
<th>4: TRANSPORTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5: PREPARATION</th>
<th>6: DISPLAY</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Not every step is described here in detail. What do you think you could add to your pictures or descriptions above? What is missing?
Practices of Paleontology (Cont.)

All scientific studies take different amounts of time to complete. In paleontology, each fossil can take a different amount of time from permission and discovery to display.

With help from your teacher, chose one of MOR’s specimens to track through this process. Use the information provided to write down the number of days each step took, then calculate the percentage of time spent on each step.

Specimen Name: ____________________________________________

<table>
<thead>
<tr>
<th></th>
<th># OF DAYS</th>
<th>% OF TOTAL TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERMISSION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DISCOVERY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXCAVATION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRANSPORTATION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PREPARATION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DISPLAY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

Total number of days from permission to display:_____________________________

What step took the most amount of time for your specimen? ________________

Why do you think that step took the longest?

Share your work with another student who studied a different specimen.

What specimen did they study? ____________________________________________

What step took the longest?_______________________________________________

Discuss with your partner why different steps in paleontology take different amounts of time for different specimens?
Scientists, including paleontologists, follow specific steps to find fossils and prepare them for display or research. Recount the key details of the practices of paleontology. Draw or write the steps below.

<table>
<thead>
<tr>
<th>1: PERMISSION</th>
<th>2: DISCOVERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Answers will vary</td>
<td>Answers will vary</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3: EXCAVATION</th>
<th>4: TRANSPORTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Answers will vary</td>
<td>Answers will vary</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>5: PREPARATION</th>
<th>6: DISPLAY</th>
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</thead>
<tbody>
<tr>
<td>Answers will vary</td>
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</tbody>
</table>

Not every step is described here in detail. What do you think you could add to your pictures or descriptions above? What is missing?
Practices of Paleontology (Cont.)

All scientific studies take different amounts of time to complete. In paleontology, each fossil can a different amount of time from permission and discovery to display.

With help from your teacher, chose one of MOR’s specimens to track through this process. Use the information provided to write down the number of days each step took, then calculate the percentage of time spent on each step.

Specimen Name: ____________________________

Total number of days from permission to display: ____________________________

<table>
<thead>
<tr>
<th></th>
<th># OF DAYS</th>
<th>% OF TOTAL TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERMISSION</td>
<td></td>
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<tr>
<td>DISCOVERY</td>
<td></td>
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<tr>
<td>EXCAVATION</td>
<td></td>
<td>Use Background Information as a reference</td>
</tr>
<tr>
<td>TRANSPORTATION</td>
<td></td>
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<tr>
<td>PREPARATION</td>
<td></td>
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<tr>
<td>DISPLAY</td>
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<tr>
<td>TOTAL</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

What step took the most amount of time for your specimen? ____________________________

Why do you think that step took the longest?

   Answers will vary

Share your work with another student who studied a different specimen.
What specimen did they study?

   Answers will vary

What step took the longest

   Answers will vary
Activity 2
Practices of Paleontology

In order to find fossils, you first need to know where to look. For example, if you want to find a *Tyrannosaurus rex* you will need to find rocks that were deposited at the time that *T.rex* lived. Geologists study the Earth and make detailed maps that show where different aged rocks are exposed at the Earth’s surface. By studying a geologic map, you may identify a promising location to look for a *T. rex*. Before you can dig up a dinosaur, you next need to make sure you have permission to do so. Often you will need a special permit to excavate fossils. Once you have obtained permission, you can then go out and look for fossils. This is called prospecting. When paleontologists are prospecting, they typically spend a lot of time hiking outdoors, searching the ground for pieces of fossils. If you’re prospecting, you may find a trail of fossil pieces leading you to something eroding out of a hillside – a discovery of a fossil. At this point, it may be difficult to determine what exactly is in the hill. It could be a fossilized rib, or an entire skeleton. The only way to find out is to dig into the hill and begin excavating the fossil.

Paleontologists have to be very careful when they excavate a fossil, because they are often very fragile. Shovels, hammers, and picks may be used to remove rock but smaller brushes and chisels are used when working close to the fossil. Once the fossils are exposed, they might be coated with glues or hardeners to help keep them together during the excavation. Before the specimens are removed from the ground, it is very important to record as much information as possible about how they are positioned in the rocks. This may help you to figure out how the fossil was preserved, or how the animal died. Paleontologists take detailed notes and photographs, measurements of depth and orientation, and draw maps of how the fossils are positioned in the ground. Once all of this information is collected, it is time to carefully remove the fossils from the ground. To do this, paleontologists typically coat fossils in layers of burlap and plaster, called a field jacket. A field jacket is similar to the cast a doctor might put around a broken arm; just as that cast is made to protect a broken bone,
Activity 2
Practices of Paleontology (Cont.)

A field jacket is made to protect the fossil as it is transported from the field back to the museum. The size of a field jacket depends on what's inside; sometimes a field jacket is very small and you can carry it out of the field in your hand; sometimes field jackets are so large and heavy that a helicopter is required to lift it and carry it to a truck for transport back to the museum.

Once back at the museum, the field jackets are opened and the remaining rock must be carefully removed from around the fossil. During preparation, scientists use picks and brushes to carefully remove the rock that has encased the fossil for millions of years. Sometimes, if the rock is very hard, they may need to use more powerful tools, such as an air scribe, which is like a small jackhammer that chips away hard rock bit by bit. Preparators fit together any broken pieces of the fossil, so that it can be studied. Sometimes fossils can take weeks, months, or even years to prepare, depending on how fragmented they are and how hard the rock encasing them is.

Once the fossil is prepared, it goes into the museum's fossil collections. The collections area is like a library, but instead of books, it contains fossils. Each specimen is assigned a number and entered into a computer database. This allows the museum to keep track of each fossil. The fossil is stored on a shelf or in a cabinet. Now that the fossil is cataloged, it can be available for research, education, or display in a museum exhibition.
The fossils you see in the “Muddy Grave” display at Museum of the Rockies are a type of sauropod called *Diplodocus*. These fossils are all from juveniles, or babies. This story describes how paleontologists found these fossils and how they ended up on display here at MOR.

In order to find fossils, you first need to know where to look. For example, the paleontologists that wanted to find the *Diplodocus* fossils you see here, needed to find rocks that were deposited at the time that *Diplodocus* lived. Geologists study the Earth and make detailed maps that show where different aged rocks are exposed at the Earth’s surface. MOR paleontologists studied a geologic map, and identified a promising location to look for a *Diplodocus*.

Before these paleontologists went out digging, they had to ask permission to do so. MOR paleontologists needed a special permit to excavate fossils. Once they had permission, they went out and looked for fossils. This is called prospecting. When paleontologists are prospecting, they typically spend a lot of time hiking outdoors, searching the ground for pieces of fossils. As these paleontologists were looking around, they found a trail of fossil pieces leading them to fossils eroding out of a hillside. They made a discovery. At this point, it was difficult to determine what exactly was there. In this case, it looked like many fossils all mixed up in what scientists call a bone bed. The only way they could find out what was there was to begin excavating the fossil.

Paleontologists were very careful when they excavated these fossils, because they are very fragile. They used shovels, hammers, and picks to remove rock but then had to use smaller brushes and chisels when they were working close to the fossil.

Before these fossils were removed from the ground, they recorded as much information as possible about how they are positioned in the rocks. You can see their drawings of these fossils from the field on the exhibit panel. These drawings helped them figure out how these dinosaurs died. Paleontologists took detailed notes and photographs, measurements of depth and orientation, and drew maps.
Activity 2

Practices of Paleontology (Cont.)
For the “Muddy Grave” display at Museum of the Rockies

of how the fossils are positioned in the ground. In this case, these drawings helped them put the fossils in this display the same way they found them in the field, so you can pretend to be a paleontologist today.

Once all of this information was collected, it was time to carefully remove the fossils from the ground. To do this, paleontologists coated the fossils in layers of burlap and plaster, called a field jacket. You may have seen a field jacket as you entered the hall in the Viewing Lab. A field jacket is similar to the cast a doctor might put around a broken arm; just as that cast is made to protect a broken bone, a field jacket is made to protect the fossil as it is transported from the field back to the museum. The size of a field jacket depends on what’s inside; sometimes a field jacket is very small and you can carry it out of the field in your hand; sometimes field jackets are so large and heavy that a helicopter is required to lift it and carry it to a truck for transport back to the museum.

Once back at the museum, the field jackets these dinosaurs fossils were in were opened and the remaining rock was carefully removed from around the fossil. You may have seen volunteer preparators doing this in the Viewing Lab. During preparation, scientists use picks and brushes to carefully remove the rock that has encased the fossil for millions of years. Sometimes, if the rock is very hard, they may need to use more powerful tools, such as an air scribe, which is like a small jack-hammer that chips away hard rock bit by bit. Preparators fit together any broken pieces of the fossil, so that it can be studied. Sometimes fossils can take weeks, months, or even years to prepare, depending on how fragmented they are and how hard the rock encasing them is.

Once these fossil were prepared, they were entered into the museum’s fossil collections. The collections area is like a library, but instead of books, it contains fossils. Each specimen is assigned a number and entered into a computer database. This allows the museum to keep track of each fossil.
Activity 2

Practices of Paleontology
For the “Muddy Grave” display at Museum of the Rockies

After the fossils were cataloged, they were studied. Paleontologists researched how the baby Diplodocus leg bones were found, the type of rock they were found in, and other clues around the fossils to hypothesize how these baby dinosaurs died. What do you think happened to these dinosaurs?

The story of these Diplodocus dinosaurs was so interesting that the research on these fossils was published and the Museum recreated the dig site in this display. The other fossils in the Dinosaurs Under the Big Sky exhibit have similar stories. But not all fossils can be displayed. In the Museum’s basement, thousands of other fossils are held in collections and are studied by researchers to help us all understand how dinosaurs lived and died.
Practices of Paleontology: Excavation
Activity 2
Practices of Paleontology: MOR 555

Wankel *T. rex* (Nation’s *T. rex*)
*Tyrannosaurus rex* MOR 555

Meaning of Name: Tyrant Lizard King
Location Found: Nelson Creek area of Fort Peck Lake, McConne County, Montana
Rock Formation: Hell Creek Formation

Year discovered: 1988
Year first displayed: 1990 in a temporary preparation lab at Museum of the Rockies

Permission
Museum of the Rockies had to obtain a permit from two federal agencies because the skeleton was located on Army Corps of Engineers land within the Charles M. Russell National Wildlife Refuge.
The permit applications took three weeks to approve for each of the two years (1989 & 1990) that the fossil was excavated.

Discovery
With this fossil, the discovery happened first. Cathy Wankel found fragments of bones in 1988. She contacted Museum of the Rockies that visited the site, then asked permission to excavate.

Excavation
1989  MOR staff began excavation on September 9, 1989. Since there was limited time, the crew decided to cover the exposed bones with a winter field jacket made from plaster soaked burlap. The field jacket protected the exposed bone until the crew could return the following year. This first phase of the excavation process took 14 days.
Activity 2
Practices of Paleontology: MOR 555 (Cont.)

1990
MOR staff returned to continue excavation on June 4. It took 10 days to remove the rock on top of the fossil and another week to uncover the entire skeleton. Since most of the skeleton was articulated, the crew had to make several large field jackets with plaster soaked burlap. These large field jackets required multiple layers of plaster and burlap and were strengthened with large timbers. The largest field jacket containing the pelvis and left leg weighed almost 4 tons. The excavation was completed over a period of 25 days on July 1.

Transportation
On July 2, the field jackets were lifted with a large front-end loader and placed on a small flatbed truck where they were shuttled to a main road. It took four trips to get all of the field jackets to the main road. On July 3, it took 7 hours to transport all of the field jackets to the Museum of the Rockies.

Preparation
Preparation of the arm took approximately two weeks by one preparator. Preparation of the skeleton took approximately two years.

Display
It was originally displayed from 1990 to 1992 in a temporary viewing lab so the public could watch how the bones were being prepared. In September 2001, a bronze replica of the skeleton was installed in the front of the Museum of the Rockies. It was on display in its original death pose in the Hall of Horns and Teeth at the Museum of the Rockies from 2005 to 2014. It was taken off display in early 2014 for packing and crating and later shipped to the National Museum of Natural History in Washington, D.C. There are more than 25 replicas of the Wankel *T. rex* skeleton and skull exhibited in museums around the world. A replica skull is currently on display as part of a *T. rex* ontogenetic series in the Tyrant Kings exhibit at the Museum of the Rockies.

In April, 2014, the real Wankel *T. rex* specimen was transported to the Smithsonian National Museum of Natural History in Washington D.C.
Activity 2
Practices of Paleontology: MOR 1122

Torosaurus MOR 1122
Meaning of Name: Perforated Lizard
Location Found: Fergus County, Montana
Rock Formation: Hell Creek Formation

Year discovered: 2000
Year first displayed: 2001 in a temporary display at Museum of the Rockies

Permission
This fossil was found on private land. Paleontologists are required to get permission from a landowner before any work takes place, including prospecting, collecting, or excavation. Museum of the Rockies was granted permission in one day.

Discovery
This fossil was discovered by Merl & Gladys Busenbark in one day.

Excavation
The skull was partially collected before final excavation by MOR, which took two weeks. The skull was protected with a field jacket made from plaster soaked burlap. It was reinforced with lumber.
Activity 2
Practices of Paleontology: MOR 1122 (Cont.)

Transportation
A Montana National Guard Blackhawk helicopter lifted it out and placed it on the ground. Using a large truck, it was lifted onto a trailer, all in one day. It took a second day to transport the field jacket to the Museum of the Rockies.

Preparation
Preparation took four weeks to complete by a team.

Display
The specimen is on display in the Hall of Horns and Teeth at the Museum of the Rockies. A cast (replica of the underside of the frill) is also on display with the real specimen. A mold of the entire skull was made in 2004. Part of the skull was missing and was reconstructed before molding took place. Casting, mounting and painting the skull took three people two weeks in various stages.
Activity 2
Practices of Paleontology: MOR 3027

Yoshi’s Trike
*Triceratops* MOR 3027
Meaning of the Name: Three-Horned Face
Location Found: Garfield County, Montana, on lands administered by the Bureau of Land Management (BLM)
Rock Formation: Hell Creek Formation

Permission
In this case, the Museum of the Rockies had to obtain a permit from the Bureau of Land Management, a federal agency within the United States Department of Interior. It took five weeks to get a permit approved.

Discovery
The partial skull and skeleton was discovered by Dr. Yoshihiro Katsura in the badlands of eastern Montana in one day.

Excavation
Museum of the Rockies started excavating the skull in 2010. The process took two weeks. More staff were needed to excavate the skeleton, which took one month. The skull and skeleton were protected with numerous field jackets made from plaster soaked burlap. Larger field jackets were reinforced with lumber.
Activity 2
Practices of Paleontology: MOR 3027 (Cont.)

Transportation
Smaller field jackets were transported by a large, six-wheel ATV. The larger skeletal field jackets were transported by helicopter to a flatbed trailer. The specimen was then transported back to the Museum of the Rockies in one day.

Preparation
It took about six months total time to finish the preparation by one staff member.

Display
All of the bones from the partial skull and skeleton were molded and cast (replicated) in plastic. The missing parts of the skull and skeleton were sculpted by a scientific artist. The missing parts were then molded and cast. The replica bones were mounted on a steel structure and the skeleton was painted to show which bones were original (brown), and those that were sculpted (white). It took five people approximately 9 months to complete the process.
Activity 2
Practices of Paleontology: MOR 979

*Thescelosaurus MOR 979*
Meaning of the Name: Wonderful Lizard
Location Found: Makoshika State Park, Glendive, Montana
Rock formation: Hell Creek Formation

Year discovered: 1997
Year first displayed: 2005 (cast) at Museum of the Rockies

Permission
In this case, the Museum of the Rockies had to obtain a permit from the Montana Fish, Wildlife and Parks department prior to working in Makoshika State Park, which was processed over five weeks.

Discovery
The skeleton was discovered while prospecting the hills of Makoshika State Park. A crewmember noticed bone fragments coming out of a hill. The crew explored the hill by using rock hammers and located more bone. While taking a break that day, the Crew Chief noticed an interesting rock that had rolled away from the hill where the fragments were found. When he rolled the rock over, he realized he was holding a part of the Thescelosaurus skull! This was all in one day.
Activity 2
Practices of Paleontology: MOR 979 (Cont.)

Excavation
A crew of four from Museum of the Rockies took six weeks to excavate the skeleton. Heavy equipment such as jackhammers had to be used because of the unusually hard sandstone the skeleton was in. The skeleton was articulated and protected with a field jacket made from plaster soaked burlap. It was reinforced with lumber.

Transportation
The field jacket was airlifted from the site by helicopter and was flown to a nearby trailer in the park, which took one day. The specimen was then transported back to the Museum of the Rockies on a second day.

Preparation
Preparation of the skeleton was extremely difficult because of the hardness of the rock. Over a three-year period, four part-time fossil preparators worked with air scribes to remove the matrix, or rock surrounding the fossil. The skeleton is still encased in rock and preparation has not been completed. With new, more effective air tools and equipment, it would probably take an experienced full-time preparator more than a year to completely prepare the skeleton.

Display
Because of the size and weight of the specimen, the skeleton in the rock was molded, cast and painted for exhibition in the Dinosaurs Under the Big Sky exhibit.
A CHANGING LANDSCAPE
Activity Overview

BIG IDEA
The Earth and its landscapes change over time. Scientists use the fossil record to understand the Earth’s environments and climates millions of years ago.

OBJECTIVE
Students will use representations of the fossil record to explore large-scale geographical changes that occur over a long period of time in what is now Montana.

BACKGROUND
The Western Interior Seaway was a shallow inland sea that split North America in two during the Middle to Late Cretaceous. Coinciding with the rise in global sea levels during the Early Cretaceous, two great arms of water—one from the north and one from the south—flooded the central low-lying interior of North America. By the start of the Late Cretaceous, approximately 100 million years ago, these two arms linked to form the Western Interior Seaway. To the west, the seaway was flanked by the rising Rocky Mountains, while relatively low and flat areas existed along its eastern shore.

The existence of the Western Interior Seaway is recorded in the rocks. Within the seaway, blankets of sand and silt were laid down along the shorelines and in shallow water settings, eventually becoming rock formations such as the Eagle Sandstone, which now form the cliffs above Billings, Montana. Deeper portions of the sea were carpeted in mud, found today in formations such as the Thermopolis Shale and Belle Fourche Shale.

The Western Interior Seaway was a defining feature of the Middle and Late Cretaceous in Montana. It was inhabited by abundant marine life including aquatic birds. Periodically, volcanic eruptions in the Rocky Mountains dumped loads of ash into the sea, found today as beds of bentonite clay. As time moved on, sea levels continued to fluctuate, repeatedly flooding and then exposing low-lying areas along the shoreline. In Montana this resulted in an alternating record of marine and terrestrial rocks, some of which have been exposed to reveal fossils like those seen in the display below the marine mural.
Jurassic fossils from Montana include fossils from the Sundance Formation (160 million years old) and the Morrison Formation (150 million years old).

The Sundance Formation was deposited in the Sundance Sea—a long, shallow inland extension of the Arctic Ocean. There is no evidence that any plants or animals dwelled on the bottom of this sea. Fossils found in the thinly bedded siltstones include one species of fish, some invertebrates (like the cephalopod), and a variety of aquatic and flying insects, none of which were land-based. The intact bodies of the fossilized fish and insects indicate that the sea floor was probably stagnant and oxygen-poor. The Morrison Formation represents the coastal plain of the Sundance Sea. It was deposited as sandstones and mudstones by rivers and streams. In most of Montana, the Morrison Formation is red or green, indicating alternating episodes of oxidation and reduction, and a relatively dry climate.

During the Late Cretaceous, sea levels continued to drop as the land uplifted and the Cretaceous Seaway receded east. The area was semiarid with extensive fern plains. Deciduous trees lined the waterways and forests of conifers grew between the waterways. Because deciduous plants grow for a period and then go dormant, animals can feed in different areas at different times of the year. Herds of duck-billed and horned dinosaurs migrated across the plains. The Two Medicine Formation, along the east front of the Rocky Mountains in Montana, represents the upland area of the original coastal plain. Farther east, the Judith River Formation represents the lowland area of the coastal plain. The marine Bearpaw Formation overlies the Judith River Formation and much of the Two Medicine Formation. Abundant marine organisms have been found in the Bearpaw Formation including clams, cephalopods, snails, crustaceans, various fishes, mosasaurs and plesiosaurs (DBS, pp. 70-76). An amazing array of dinosaur specimens from the Late Cretaceous has been found in Montana including Maiasaura, Troodon, Daspletosaurus, Hypacrosaurus, Brachylophosaurus, Saurornitholestes, and Stegoceras.
A CHANGING LANDSCAPE
Museum Instructions

MATERIALS
MOR Outreach Kit: Geologic Time including examples of the four rock formations highlighted in this activity and fossil specimens from highlighted species

LOCATION

ACTIVITY TIME
45 Minutes

INSTRUCTIONS
This activity can be used to support geology lessons involving plate tectonics or sedimentary rocks.

Provide your students with an example of something that has changed in your hometown in the past two years (buildings, trees, etc.). Ask your students if they can think of anything else that has changed in their landscape.

Tell the students that they will be exploring how the Earth has changed over a long period of time, millions of years, and how we know that even though no human was alive during this time.

Help students understand that while we may not see changes in the landscape in our lifetime, what is now Montana looks very different than it did at the time of the dinosaurs.
A CHANGING LANDSCAPE
Museum Instructions (Cont.)

Ask your students how scientists know the Earth has changed or what it looked like if no one was alive to see the dinosaurs. How do we know dinosaurs existed? (We find their fossils.) How do we know what plants surrounded the dinosaurs? (We find trace fossils in the sedimentary rocks. Trace fossils are impressions, like a footprint, that preserve the imprint of an organism in the sediment.) If available, use examples of fossils provided in MOR’s Geologic Time Outreach Kit to show examples of fossils. Then ask the students, “How do we know if fossilized plants or animals were found on land or water?”. In this discussion, help students understand that the types of fossils we find (marine vs. terrestrial) provide clues, but so do the rocks themselves.

Tell your students that in this activity, they will use an activity sheet to use the same science practices to identify how Montana’s landscape changed during the time of the dinosaurs.

Using the activity sheet, instruct your students to identify the different fossils in both maps. By identifying where terrestrial fossils and rock formations are found and where marine fossils are found, help students estimate the boundary of the Western Interior Seaway.

Encourage your students to explore this concept more in depth. Using the activity sheet, ask students to compare and contrast these two time periods. Have students apply this knowledge by thinking about what their hometown would look like in the fossil record. Have students estimate the location of their hometown on the map. Discuss what types of rocks and fossils may be found.

Conclude the lesson by emphasizing that the Earth, its landscape, and its climate changes over time. Scientists can identify changes by studying the fossil record. Fossils help us understand how animals, like dinosaurs, may have behaved, but fossils also provide clues to larger Earth systems.
A CHANGING LANDSCAPE
Classroom Instructions

MATERIALS
MOR “A Changing Landscape” PowerPoint slides (or printed images of these slides); MOR Outreach Kit: Geologic Time including examples of the four rock formations highlighted in this activity and fossil specimens from highlighted species

ACTIVITY TIME
45 Minutes

INSTRUCTIONS
This activity can be used to support geology lessons involving plate tectonics or sedimentary rocks.

Provide your students with an example of something that has changed in your hometown in the past two years (buildings, trees, etc.). Ask your students if they can think of anything else that has changed in their landscape.

Tell the students that they will be exploring how the Earth has changed over a long period of time, millions of years, and how we know that even though no human was alive during this time.

If your students have not yet been introduced to plate tectonics, geologic time, or the Western Interior Seaway, use the PowerPoint slides to briefly show that the Earth has changed over millions of years. Focus your brief introduction on change; it is not critical to know details of each of the highlighted maps. Instead, help students understand that while we may not see changes in the landscape in our lifetime, what is now Montana looks very different than it did at the time of the dinosaurs.

Ask your students how scientists know the Earth has changed or what it looked like if no one was alive to see the dinosaurs. How do we know dinosaurs existed? (We find their fossils.) How do we know what plants surrounded the dinosaurs? (We find trace fossils in the sedimentary rocks. Trace fossils are impressions, like a footprint, that preserve the imprint of an organism in the sediment.) If available, use examples of fossils provided in MOR’s Geologic Time Outreach Kit to show examples of fossils. Then ask the students, how we know if fossilized plants or animals were found on land or water. In this discussion, help students understand that the types of fossils we find (marine vs. terrestrial) provide clues, but so do the rocks themselves.
Tell your students that in this activity, they will use an activity sheet to use the same science practices to identify how Montana's landscape changed during the time of the dinosaurs.

Using the activity sheet, instruct your students to identify the different fossils in both maps. By identifying where terrestrial fossils and rock formations are found and where marine fossils are found, help students estimate the boundary of the Western Interior Seaway.

Encourage your students to explore this concept more in depth. Using the activity sheet, ask students to compare and contrast these two time periods. Have students apply this knowledge by thinking about what their hometown would look like in the fossil record.

Conclude the lesson by emphasizing that the Earth, its landscape, and its climate changes over time. Scientists can identify changes by studying the fossil record. Fossils help us understand how animals, like dinosaurs, may have behaved, but fossils also provide clues to larger Earth systems.
A Changing Landscape

What did the Earth look like during the Mesozoic Era? In the area that is now Montana, what did the landscape look like and how do we know?

150 Million Years Ago

This map generally symbolizes the types of fossils that have been found and where they have been found in the rock formations dated 150 millions of years ago (mya). In this map, find and circle the shark teeth fossils. Shark teeth fossils are found in shale. Shale is formed in shallow seas. Find the *Allosaurus* fossils and draw squares around them. *Allosaurus* fossils are found in sandstone. This sandstone was formed in rivers. Using colored pencils, color in the parts of this map that were a shallow sea with blue and the areas that were land with rivers in green.

75 Million Years Ago

This map generally shows the types of fossils that have been found and where they have been found in the rock formations dated 75 millions of years ago (mya). In this map, find and circle the Ammonite fossils. Ammonite fossils are found in shale. Shale is formed in shallow seas. Find the *Brachylophosaurus* fossils and draw squares around them. The *Brachylophosaurus* fossils are found in sandstone. This sandstone was formed in rivers. Using colored pencils, color in the parts of this map that were a shallow sea with blue and the areas that were land with rivers in green.
A Changing Landscape (Cont.)

Why would *Allosaurus* or *Brachylophasaurus* fossils be found in river deposits?

How many years passed between these two maps?

Which map is older?

Based on the fossil evidence, describe how the landscape and shoreline change between 150 million years ago and 75 million years ago in what is now Montana?

What types of rock formations would future scientists find in your hometown if your landscape today was preserved in the fossil record?
A Changing Landscape

What did the Earth look like during the Mesozoic Era? In the area that is now Montana, what did the landscape look like and how do we know?

150 Million Years Ago

This map generally symbolizes the types of fossils that have been found and where they have been found in the rock formations dated 150 millions of years ago (mya). In this map, find and circle the shark teeth fossils. Shark teeth fossils are found in shale. Shale is formed in shallow seas. Find the Allosaurus fossils and draw squares around them. Allosaurus fossils are found in sandstone. This sandstone was formed in rivers. Using colored pencils, color in the parts of this map that were a shallow sea with blue and the areas that were land with rivers in green.

75 Million Years Ago

This map generally shows the types of fossils that have been found and where they have been found in the rock formations dated 75 millions of years ago (mya). In this map, find and circle the Ammonite fossils. Ammonite fossils are found in shale. Shale is formed in shallow seas. Find the Brachylophosaurus fossils and draw squares around them. The Brachylophosaurus fossils are found in sandstone. This sandstone was formed in rivers. Using colored pencils, color in the parts of this map that were a shallow sea with blue and the areas that were land with rivers in green.
A Changing Landscape

Why would Allosaurus or Brachylophasaurus fossils be found in river deposits?

*Allosaurus* and *Brachylophasaurus* both lived on land. Rivers carry sand and mud, which can bury dinosaur bones after a dinosaur dies. These deposits can become rock formations with many fossils.

How many years passed between these two maps?

\[
150 - 75 = 75 \text{ million years}
\]

Which map is older?

The map of 150 Million Years Ago (mya) with *Allosaurus* and shark teeth.

Based on the fossil evidence, describe how the landscape and shoreline change between 150 million years ago and 75 million years ago in what is now Montana?

*Dinosaurs* (which lived on land) and marine fossils suggest that the seaway and shoreline changed from 150 to 75 million years ago.

Around 150 mya what is now western Montana was covered by water.

Around 75 mya, the western part of Montana was land and the east was covered by water.

What types of rock formations would future scientists find in your hometown if your landscape today was preserved in the fossil record?

Answers will vary.
ONCE UPON A TIME
Activity Overview

BIG IDEA
The geologic time scale can be challenging for students to understand. This activity explores how scientists divide the Earth’s long history into smaller segments using plants and animals found in the fossil record.

OBJECTIVE
Students will explore the various species that dominated the Cenozoic, Mesozoic, and Paleozoic eras and the Precambrian supereon.

BACKGROUND
Paleontology combines geology and biology to study extinct organisms preserved in rocks. Knowledge of geology helps scientists know where to look, what to look for, and how old the fossils are. Geological information helps paleontologists figure out what happened to animals, what may have killed them, and what happened to their remains after they died.

Geologic time is 4.5 billion years of the earth’s history that is represented by and recorded in layers of rock. Over the course of geologic time, the continents have moved and shifted, and sea levels have risen and fallen. The geological record spans over 4 billion years. Scientists developed the geological time scale to help keep track of where fossils are found within this rock record. The scale uses units of time called supereons, eons, eras, periods, epochs and stages. Dinosaurs existed for 155 million years during the Mesozoic Era and were the dominant animal longer than any other type that has ever lived.

The Mesozoic Era lasted for 165 million years, during which time the earth underwent considerable change. The Mesozoic Era is divided into three time periods called the Triassic, Jurassic, and Cretaceous Periods.

During the Triassic Period, all the continents were joined together to form a super continent referred to as Pangea. Some of the evidence for this super continent comes from fossil animals. There are reptiles, for example, that come from Triassic Period rocks of North America that are identical to reptiles found in Triassic Period rocks of Europe and Africa. Geologic studies indicate that Pangea began to break up into today’s continents near the end of the Triassic Period.
ONCE UPON A TIME
Activity Overview (Cont.)

BACKGROUND (CONT.)
During the Jurassic Period, the continents were separating and the Atlantic Ocean was beginning to form, but there were still several large land bridges between many of the continents. As a result, many of the dinosaurs of the Jurassic Period are similar in some parts of the world.

By the Cretaceous Period most of the continents had separated and all of the oceans had formed. Only a few small land bridges remained. By the end of the Cretaceous Period, the continents were in much the same location as they are today.

EXTENSIONS
• Use the MOR Outreach Kit: Geologic Time to complete hands-on activities that can help students better understand geologic time.

• Visit Museum of the Rockies on a field trip to see fossils from the time periods in this lesson.
ONCE UPON A TIME
Museum Instructions

MATERIALS
Student activity sheets, clipboards, pencils (Pens, crayons, and markers are not allowed in exhibit spaces)

LOCATION

ACTIVITY TIME
30 Minutes

INSTRUCTIONS
This activity can be used to explore geologic time. Throughout the exhibit, students can find maps on exhibit panels showing the Earth’s land masses and oceans during different time periods. However, the best place to show the geologic time scale is in the Landforms, Lifeforms exhibit before the Dinosaurs Under the Big Sky exhibit space.

Find a space in the first room of the Landforms, Lifeforms exhibit before the Dinosaurs Under the Big Sky exhibit at MOR.

Tell your students that paleontology combines geology and biology to study extinct organisms preserved in rocks. Knowledge of geology helps scientists know where to look, what to look for, and how old the fossils are. Geological information helps paleontologists figure out what happened to animals, what may have killed them, and what happened to their remains after they died.

Geologic time is 4.5 billion years of the earth’s history that is represented by and recorded in layers of rock. Over the course of geologic time, the continents have moved and shifted, and sea levels have risen and fallen. The geological record spans over 4 billion years. Scientists developed the geological time scale to help keep track of where fossils are found within this rock record. The scale uses units of time called eons, eras,
ONCE UPON A TIME
Museum Instructions (Cont.)

INSTRUCTIONS (CONT.)

periods, epochs and stages. The scale includes four eras:
Precambrian, Paleozoic, Mesozoic and Cenozoic.

Dinosaurs existed for 155 million years during the Mesozoic Era and
were the dominant animal longer than any other type that has ever lived.

After working through the first page of the activity, have your students
explore the Landforms, Lifeforms exhibit, the Dinosaurs Under the Big
Sky exhibit, and the Cenozoic area upstairs from the Viewing Lab, to
find displays and fossils of the plants and animals that lived during each
time segment.

Have students use the displays to draw pictures on the second page of
the activity before calculating the length of each of the different
time segments.
ONCE UPON A TIME
Classroom Instructions

MATERIALS
MOR Outreach Kit: Geologic Time including ribbon of geologic timeline
50 meter measuring tape and printouts to mark key eras

ACTIVITY TIME
45 Minutes

INSTRUCTIONS
This activity can be used to support lessons involving geologic time.

Providing a demonstration for geologic time can enhance student understanding of a difficult concept. For this visual demonstration, you will need a 50 meter measuring tape and printouts to mark key eras. Take your students outside to the playground, or to a long hallway. Explain that you are going to create a timeline that will represent the age of the Earth.

1. Attach the end of the tape measure to the floor and tell students that “0” is today.
2. Have students walk the tape measure out with you.
3. At 1 meter stop and explain that 1 meter is going to represent 100 million years.
4. Continue out to the 46 meter mark; the 46 meter mark will represent the beginning of Earth, and the beginning of the Precambrian Era. Set the tape measure down and walk with your students back to “today,”
5. Stopping at 5.41 meters to introduce the beginning of the Paleozoic Era,
6. 2.52 meters to introduce the beginning of the Mesozoic Era,
7. 0.66 meters to introduce the beginning of the Cenozoic Era
8. Stop at any other key events you wish to feature (for example, oxygen appeared in earth’s atmosphere 2.45 billion years ago—24.5 meters).

When we put Earth’s timeline to scale we can better understand that living things as we think of them didn’t appear until relatively recently. After this demonstration, use the activity sheet to introduce how scientists estimate the age of the Earth. Use the materials in the Outreach Kit to introduce the common plants and animals of each time segment.
Optional Extensions for the Classroom:

1. Introduce the idea of a timescale by having students create a timeline of important events that have happened in their lives. The first event would be birth (accompanied by their birth date), and the last event would be the current date. Events in between should not be evenly spaced but to scale with the age they were when the event happened.

2. After introducing the geologic timescale with this activity and a visual demonstration, have students/student groups create their own geologic timeline on 46 inches of receipt paper, where each inch represents one hundred million years, marking the beginning of eras and other key events.

3. Have students work in groups or individually to write a report on a prehistoric animal; have the students present their information to the class in order of existence. For example coral would present first, followed by trilobites, followed by ferns, etc.
One question that people long tried to answer was: “How old is the earth?” The earliest Greek philosophers, like Aristotle, simply assumed that the earth had always been around forever. Some Southwest American Indian tribes believed that the world had been created and destroyed several times. Ancient Egyptians counted different reigns of kings back 24,950 years. The Ancient Romans tried to use written human records to count backward to the beginning of time, and came up with a date of about 2,300 BC. The Irish Bishop James Ussher used a similar technique in 1654 to come to the date of 4,004 BC for the creation of the world.

Then, in the 1840s, as people started digging and mining deeper into the earth and geologists started learning more about the earth, they realized that much of the earth had distinct layers. They found these layers as they started mining and digging deeper into the earth. Geologists noted that layers hundreds of miles apart were in very similar patterns, which they called the geologic column.

How many layers do you count in the **geologic column** to the right, including the periods in the Mesozoic Era?
Once Upon a Time (Cont.)

One problem was that geologists didn’t know how many years it took for each layer to get laid down.

Of course, they didn’t have the full picture, and not every layer is present in every place. Geologists tried several other calculations, such as the amount of salt added to the oceans, but the big breakthrough came in 1896. In 1896 Radiation was discovered, and ten years later radiometric dating was used on several types of rocks to find the oldest ones – it came out to be 4.6 billion (or 4,600 million) years.

“mya” = million years ago

<table>
<thead>
<tr>
<th>TIME SEGMENT</th>
<th>SHOW YOUR WORK</th>
<th>HOW MANY MILLIONS OF YEARS DID THIS TIME SEGMENT LAST?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cenozoic Era “ends”: 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cenozoic Era begins: 66 mya</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesozoic Era ends: 66 mya</td>
<td>Mesozoic Era begins: 245 mya</td>
<td></td>
</tr>
<tr>
<td>Paleozoic Era ends: 245 mya</td>
<td>Paleozoic Era begins: 541 mya</td>
<td></td>
</tr>
<tr>
<td>Precambrian ends: 541 mya</td>
<td>Precambrian begins: 4,500 mya</td>
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Which time segment lasted the longest?

Which time segment has lasted the shortest amount of time?
Once Upon a Time

One question that people long tried to answer was: “How old is the earth?” The earliest Greek philosophers, like Aristotle, simply assumed that the earth had always been around forever. Some Southwest American Indian tribes believed that the world had been created and destroyed several times. Ancient Egyptians counted different reigns of kings back 24,950 years. The Ancient Romans tried to use written human records to count backward to the beginning of time, and came up with a date of about 2,300 BC. The Irish Bishop James Ussher used a similar technique in 1654 to come to the date of 4,004 BC for the creation of the world.

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How many layers do you count in the geologic column to the right, including the periods in the Mesozoic Era?

6
Once Upon a Time (Cont.)

One problem was that geologists didn’t know how many years it took for each layer to get laid down.

Of course, they didn’t have the full picture, and not every layer is present in every place. Geologists tried several other calculations, such as the amount of salt added to the oceans, but the big breakthrough came in 1896. In 1896 Radiation was discovered, and ten years later radiometric dating was used on several types of rocks to find the oldest ones – It came out to be 4.6 billion (or 4,600 million) years.

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</tr>
</thead>
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| Cenozoic Era “ends”: 0  
Cenozoic Era begins: 66 mya | 66 - 0 = 66 | |
| Mesozoic Era ends: 66 mya  
Mesozoic Era begins: 245 mya | 245 - 66 = 179 | |
| Paleozoic Era ends: 245 mya  
Paleozoic Era begins: 541 mya | 541 - 245 = 296 | |
| Precambrian ends: 541 mya  
Precambrian begins: 4,500 mya | 4,500 - 541 = 3,959 | 3,959 million years or 3.96 billion years |

Which time segment lasted the longest? ________________________________

Which time segment has lasted the shortest amount of time? ________________________________

Precambrian

Cenozoic
DINOSAUR... OR NOT?
Activity Overview

BIG IDEA
Not all prehistoric or extinct animals are dinosaurs. Dinosaurs have specific characteristics that set them apart from other reptiles and marine animals. Modern birds have descended from dinosaurs.

OBJECTIVE
Students observe patterns in various prehistoric creatures and determine whether or not they can be classified as dinosaurs.

BACKGROUND
When scientists classify different species of animals they look at shared features such as skeletal structure and function. Dinosaurs are descended from a group of earlier reptiles. Early reptiles were like “modern” reptiles in that they lived on land and had a sprawling gait – that is, their legs stuck out to the sides of their bodies, like crocodiles and lizards. Dinosaurs shared many characteristics with these earlier reptiles, but dinosaurs’ legs supported their body weight by being directly under their bodies. In addition, dinosaurs were terrestrial. That is, they lived on the land, rather than through the air or in the water. In summary, all dinosaurs shared these four characteristics:

• All dinosaurs were vertebrates.
• All dinosaurs lived on land (not in the air or sea).*
• All dinosaurs were reptiles whose legs support their bodies from directly underneath, not sprawled out to the side.
• All dinosaurs lived during the Mesozoic Era, 245 to 66 million years ago. (However, not all animals that lived at this time were dinosaurs.)

If an animal doesn’t meet these characteristics, then they were not a dinosaur.

*Birds, however are a special case. Birds share characteristics with some dinosaurs: wishbone, hollow bones, extra-long digit (finger) on the hand, oblong hard-shelled eggs, wrist bone that allows the bird wing to fold to the side of the arm, three-toed foot, feathers. It is widely accepted by paleontologists that birds are the descendants of small, two-legged, feathered (theropod) dinosaurs with some new features like a beak instead of a toothed jaw and the “loss” of some fingers. By studying the similar structures and functions of dinosaur and bird fossils, scientists argue that birds are descended from dinosaurs.
DINOSAUR... OR NOT?
Activity Instructions (Cont.)

This is similar to how a person could consider themselves Irish if they are descended from Irish ancestors. Scientists have a special name for birds: avian dinosaurs!

EXTENSIONS

• Use the MOR Outreach Kit: Practices of Paleontology, to this process in more depth and facilitate a mock fossil preparation activity.
• Visit Museum of the Rockies on a field trip to see the real fossils described in this activity on display.
DINOSAUR... OR NOT?
Museum Instructions

MATERIALS
Student activity sheets, clipboards, colored pencils (Pens, crayons, and markers are not allowed in exhibit spaces)

ACTIVITY TIME
30 Minutes

INSTRUCTIONS
Review the background information with your students, and work through the activity provided in this section. As you go through the museum, use the four dinosaur characteristics to decide if each animal you encounter is a dinosaur or not. Animals in the exhibit that are not dinosaurs:

Landforms and Lifeforms
None of these sea creatures were dinosaurs. Most of them were invertebrates, and they lived in the seas during the Paleozoic – the time before dinosaurs.

Plesiosaurs and Marine Crocodile
While these animals lived during the right time period in the Mesozoic, and have made fossils when they died, they were not dinosaurs. Ask your students if they can pick out why they were not really dinosaurs. Because they lived in the ocean, plesiosaurs were not dinosaurs. Crocodiles are also reptiles and distantly related to dinosaurs, but their legs sprawl off to the sides of their bodies, so are also not dinosaurs.

Small River Crocodile and Turtle
Since these animals are reptiles, with sprawling legs, they are also not dinosaurs, even though they may have spent time on land.
DINOSAUR... OR NOT?
Classroom Instructions

MATERIALS
MOR Outreach Kit: Dinosaur Basics including 20 Paleontology models
Plastic animals for dinosaur sorting activity
Guide to dinosaur sorting activity Signs: “Dinosaur” and “Not a Dinosaur”
Two bins for dinosaur sorting activity (optional for larger groups)

ACTIVITY TIME
20 Minutes

INSTRUCTIONS
Without providing any background information to your group on dinosaurs, show the participants the plastic animal toys (provided in the MOR Outreach Kit). Have the participants help you sort the animals according to if they are or are not a dinosaur.

For smaller groups, give every child a toy. Ask the participants to hold on to their animal and move to one side of the room or the other depending on if they are or are not a dinosaur. Show students which side is which by posting a sign, having an adult hold each sign, or write it on your whiteboard.

When the children have all sorted themselves, have everyone sit down. Have each child share their animal and why they thought it is or is not a dinosaur. While children share, confirm that they are in the correct group by using the provided four characteristics of dinosaurs listed earlier. Have participants move to the correct group if they guessed incorrectly.
Dinosaur... Or Not?

Study the images of the dinosaurs and the animals that are not dinosaurs. Circle the dinosaurs.

How are the legs of the dinosaurs different than the animals that are not dinosaurs?

What class do dinosaurs belong to? (circle one): mammal reptile amphibian fish

Modern birds and dinosaurs share many characteristics. Describe three traits that dinosaurs and birds have in common.

1. ________________________________________________________________
2. ________________________________________________________________
3. ________________________________________________________________
Animals with bodies that are well-adapted to their environment can thrive for millions of years. Dinosaurs lived for 165 million years. While birds evolved from dinosaurs and are alive today, larger land-dwelling dinosaurs went extinct 66 million years ago.

Scientists hypothesize that dinosaurs went extinct when a large meteor hit the Earth. Describe how this would have changed the Earth’s environment.

Some animals, including small reptiles and mammals survived this environmental change. What characteristics did these animals have that helped them survive?

**Build-A-Dino:** You have discovered a new dinosaur with some unique characteristics. Circle one item from each box of traits on the left hand side. Then, draw your new dinosaur discovery that has each of those characteristics. Paleontologists never know what they are going to discover!

<table>
<thead>
<tr>
<th>Traits</th>
<th>New Dinosaur Name:</th>
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<tbody>
<tr>
<td>Two-Legged</td>
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<tr>
<td>Very Large</td>
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<tr>
<td>Large</td>
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</tr>
<tr>
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<td></td>
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<tr>
<td>Bony Armor</td>
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<tr>
<td>Sharp Teeth and Claws</td>
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<tr>
<td>Spikes on Back and Tail</td>
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<tr>
<td>Feathers</td>
<td></td>
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<tr>
<td>Scales</td>
<td></td>
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</tbody>
</table>
Study the images of the dinosaurs and the animals that are not dinosaurs. Circle the dinosaurs.

How are the legs of the dinosaurs different than the animals that are not dinosaurs?

**Dinosaurs had legs directly underneath their bodies.**

What class do dinosaurs belong to (circle one): mammal  reptile  amphibian  fish

Modern birds and dinosaurs share many characteristics. Describe three traits that dinosaurs and birds have in common.

1. ____________________________ Feathers
2. ____________________________ Wishbone
3. ____________________________ Hollow bones
4. ____________________________ Legs directly underneath body
5. ____________________________ 3-toed foot
6. ____________________________ Hard-shelled eggs
Animals with bodies that are well-adapted to their environment can thrive for millions of years. Dinosaurs lived for 165 million years. While birds evolved from dinosaurs and are alive today, larger land-dwelling dinosaurs went extinct 66 million years ago.

Scientists hypothesize that dinosaurs went extinct when a large meteor hit the Earth. Describe how this would have changed the Earth’s environment.

**A large meteor impact may have sent clouds of dust into the atmosphere, which blocked sunlight, cooling the earth for many years.**

Some animals, including small reptiles and mammals survived this environmental change. What characteristics did these animals have that helped them survive?

**These small animals are typically very adaptable. Small animals require less food and water, which can help survival in a catastrophe.**

**Build-A-Dino:** You have discovered a new dinosaur with some unique characteristics. Circle one item from each box of traits on the left hand side. Then, draw your new dinosaur discovery that has each of those characteristics. Paleontologists never know what they are going to discover!

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Answers and drawings will vary
SORT-A-SAURUS
Activity Overview

BIG IDEA
This activity introduces students to the five main groups of dinosaurs.

OBJECTIVE
Students will make observations of each group of dinosaurs.

BACKGROUND
Why do we sort dinosaurs into five main groups? As paleontologists discovered more and more dinosaurs, they grouped them into different groups based on their similarities, a branch of science called phylogenetics or cladistics. Each of these “families” is known as a clade. There are many species of dinosaurs in each clade, but every member of the “family” shares characteristics and behaviors. Paleontologists break down these five families even farther, which students can do or research as an extension.

Theropods walked on two legs, were predatory, and varied widely in size. T. rex, Velociraptor, Deinonychus, and others, were Theropods. Theropods evolved feathers to keep warm in the middle Jurassic; some of these theropods evolved into birds. There is evidence that all theropods had feathers at some point in their development. For instance, a Juvenile member of the Tyrannosaurids was found in China with feathers, so it seems that even T.rex may have had feathers when they were young. These feathers may have been mostly for warmth for the larger Theropods.

Sauropods had long necks, long tails, small heads, and 4 thick legs. Diplodocus and Argentinosaurus were Sauropods.

Ceratopsians are characterized by horns or frills on or around their faces. Triceratops and Montanoceratops were Ceratopsians. The horns may appear to be used for defense against predators, but some Ceratopsians had horns that would have been truly useless as true defense.

Ornithopods were duck-billed, meaning that the front of their skull and mouth is flat, like a duck; some had a crest on top of their head. Charanosaurus and Edmontosaurus were Ornithopods.

Thyreophorans were armored dinosaurs with thick plates on their back; some have spiked tails. Ankylosaurus and Stegosaurus were Thyreophorans.
SORT-A-SAURUS
Activity Overview (cont.)

BACKGROUND (CONT.)
Discuss with your students how dinosaurs in these different groups must have used their adaptations in their environment. For example, Theropods moved on two legs, allowing them to run fast and catch prey; the frills and horns of the Ceratopsians offered these large herbivores protection from carnivores; the Hadrosaurid duckbill allowed it to easily graze on plant material low to the ground and burrow in mud.

EXTENSIONS
After completing the Sort-a-Saurus Activity, assess your students’ understanding of grouping by common traits by having students draw a dinosaur from their imagination that would belong in a specified group. For example, “Draw me a dinosaur from your imagination that would be a part of the Ceratopsian family.” The imagined dinosaurs should all have some sort of horn arrangement or frills around their heads. If a student’s dinosaur does not match the specified group, see if the class can determine which family it would belong to.

At the Museum, challenge your students to find an example of each type of dinosaur.
START WITH YOUR STUDENTS NEAR THE SAUROPOD NECK IN THE HALL OF GIANTS. TELL YOUR STUDENTS THAT THERE ARE HUNDREDS OF DIFFERENT SPECIES OF DINOSAURS, AND MORE ARE DESCRIBED EVERY DAY. HOW CAN WE SORT THROUGH ALL THE DIFFERENT SPECIES? PALEONTOLOGISTS HAVE CLASSIFIED DINOSAURS BASED ON THEIR SKELETAL STRUCTURES AND BODY CHARACTERISTICS. THESE DIFFERENT CATEGORIES ARE CALLED ORDERS OR CLADES, BUT THEY CAN BE CONSIDERED A “FAMILY” OF DINOSAURS. FOR EXAMPLE, EACH MEMBER OF THE “CAT FAMILY” TODAY SHARES CERTAIN CHARACTERISTICS, LIKE FUR, SHARP TEETH, CLAWS, AND DECENT NIGHT VISION. EACH “DINOSAUR FAMILY” Likewise SHARES CERTAIN CHARACTERISTICS, AND ARE DIFFERENT THAN OTHER “FAMILIES.”

ASK YOUR STUDENTS TO STAY SEATED, BUT LOOK AROUND THE HALL. DO THEY SEE DINOSAURS WITH DIFFERENT BODY SHAPES? TELL THEM THAT TODAY, THEY ARE GOING TO EXPLORE THE DIFFERENT DINOSAUR FAMILIES IN THE DINOSAURS UNDER THE BIG SKY EXHIBIT.

USE THE ACTIVITY SHEET TO EXPLORE THE DINOSAUR FAMILIES.

AFTER COMPLETING THE ACTIVITY SHEET, CHALLENGE YOUR STUDENTS TO FIND AN EXAMPLE OF EACH TYPE OF DINOSAUR.
SORT-A-SAURUS
Classroom Instructions

MATERIALS
MOR Outreach Kit: Dinosaur Basics (including plastic dinosaurs and family names printed), an assortment of items from your classroom for sorting

ACTIVITY TIME
30 Minutes

INSTRUCTIONS
In groups, or individually, provide your students with an assortment of objects from your classroom. Ask your students to sort these objects into groups and allow your students time to move their objects into “like” piles. Have your students share with the whole class how they sorted their objects. Tell your students that just like they have done with objects from their classroom, scientists classify different organisms by the characteristics they share.

Tell your students that there are hundreds of different species of dinosaurs, and more are described every day. How can we sort through all the different species? Paleontologists have classified dinosaurs based on their skeletal structures and body characteristics. These different categories are called orders or clades, but they can be considered a “family” of dinosaurs. For example, each member of the “cat family” today shares certain characteristics, like fur, sharp teeth, claws, and decent night vision. Each “dinosaur family” likewise shares certain characteristics, and are different than other “families.”

Use the activity sheet to explore the dinosaur families.

After students have completed the activity sheet, use the plastic dinosaurs to assess their understanding. Have students help you sort the dinosaurs into the families described on the activity sheet.

Discuss with your students how dinosaurs in these different groups must have used their adaptations in their environment. For example, Theropods moved on two legs, allowing them to run fast and catch prey; the frills and horns of the Ceratopsians offer these large herbivores protection from carnivores; the Hadrosaurid duckbill allowed it to easily graze on plant material low to the ground and burrow in mud.

Using the last question of the activity page, have your students brainstorm a category of animal or objects that you’re interested in (mammals, cars, sports). Can you sort them into a few sets of “families?”
Sort-A-Saurus!

There are hundreds of different species of dinosaurs, and more are described every day. How can we sort through all the different species? Paleontologists have classified dinosaurs based on their skeletal structures and body characteristics. These different categories are called orders or clades, but they can be considered a “family” of dinosaurs. For example, each member of the “cat family” today shares certain characteristics, like fur, sharp teeth, claws, and decent night vision. Each “dinosaur family” likewise shares certain characteristics, and are different than other “families.”

Look at skeletons of each of the five dinosaur “families” pictured on this activity sheet and write a description of characteristics that all members of that “family” share. Then, share your descriptions of each “family” with your class.

**THEROPODS**

What characteristics do all Theropods share? __________________________________________

**SAUROPODS**

What characteristics do all Sauropods share? __________________________________________
Sort-A-Saurus! (Cont.)

**CERATOPSIANS**
What characteristics do all Ceratopsians share?

![Ceratopsian dinosaurs](image)

**ORNITHOPODS**
What characteristics do all Ornithopods share?

![Ornithopod dinosaurs](image)

**THYREOPHORANS**
What characteristics do all Thyreophorans share?

![Thyreophoran dinosaurs](image)

Think of a category of animal or objects that you’re interested in (mammals, cars, sports). Can you sort them into a few sets of “families?”
There are hundreds of different species of dinosaurs, and more are described every day. How can we sort through all the different species? Paleontologists have classified dinosaurs based on their skeletal structures and body characteristics. These different categories are called orders or clades, but they can be considered a “family” of dinosaurs. For example, each member of the “cat family” today shares certain characteristics, like fur, sharp teeth, claws, and decent night vision. Each “dinosaur family” likewise shares certain characteristics, and are different than other “families.”

Look at skeletons of each of the five dinosaur “families” pictured on this activity sheet and write a description of characteristics that all members of that “family” share. Then, share your descriptions of each “family” with your class.

**THEROPODS**

What characteristics do all Theropods share? ____________________________

---

**SAUROPODS**

What characteristics do all Sauropods share? ____________________________

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**Skeletal Images**

- Theropods: Walk on 2 legs
- Sauropods: Long necks and tails, small heads
Sort-A-Saurus! (Cont.)

CERATOPSIANS
What characteristics do all Ceratopsians share? Horns or frills around their face

ORNITHOPODS
What characteristics do all Ornithopods share? Duck-billed, flat mouths

THYREOPHORANS
What characteristics do all Thyreophorans share? Armor or plates

Think of a category of animal or objects that you’re interested in (mammals, cars, sports). Can you sort them into a few sets of “families?”
HOW BIG?
Activity Overview

BIG IDEA
The immensity of Sauropods and *T. rex* can often fool us into thinking all dinosaurs were giants. However, in reality, dinosaurs varied greatly in size. In the second part of this activity, students will brainstorm inherent advantages of large and small dinosaurs.

OBJECTIVE
Students will compare the weights of various dinosaurs to familiar items to understand the wide variation in size.

BACKGROUND
Dinosaurs varied greatly in size and structure. The heaviest dinosaur known was *Argentinosaurus*, weighing in at 60-100 tons! At only 13 inches long and weighing under a quarter of a pound, *Anchiornis huxleyi* was the smallest known non-avian dinosaur. Both large and small dinosaurs had unique advantages that helped them to survive. For example, large dinosaurs, like sauropods had long necks which gave them a better view of their surroundings and any approaching danger. Small dinosaurs were typically lighter and could move faster and hide more easily to escape larger predators. Encourage students to brainstorm other advantages dinosaurs may or may not have had because of their size.

To include the scientific method, have students think of modern animal behavior they have observed. Based on their observations of both small and large animals, have them create hypotheses about dinosaur behavior. For example: “The mouse is a small animal and has to be very fast to escape predators like cats. Therefore, smaller dinosaurs were probably faster so they could escape larger dinosaurs that may try to eat them.”

EXTENSION
Have students compare the weights of the dinosaurs in the activity by using <, >, and = between the pictures of the dinosaurs. To further incorporate Number and Operations in Base 10, have students write the dinosaurs’ weights in scientific notation.
HOW BIG?

Museum Instructions

MATERIALS
Student activity sheets, clipboards, pencils (Pens, crayons, and markers are not allowed in exhibit spaces)

ACTIVITY TIME
30 Minutes

LOCATION
Find a space in the Dinosaurs Under the Big Sky exhibit at MOR.

INSTRUCTIONS
This activity can be used to explore the sizes of dinosaurs. Students can travel throughout the exhibit to estimate sizes of animals on display, however, the best place to introduce the topic is under the Diplodocus neck, in the Dinosaurs Under the Big Sky exhibit, just after the viewing lab.

Tell your students that the branch of paleontology that is studied here at the museum is ontogeny, which is the science of how things change as they grow. Throughout the Dinosaurs Under the Big Sky exhibit, you’ll see growth series of different dinosaurs – Diplodocus, Maiasaura, Triceratops, Pachycephalosaurus, and Tyrannosaurus. While this might give the idea that dinosaurs were all truly giants, there were actually many smaller species of dinosaur. The average size of a dinosaur was about the same size as a sheep. We can use the activity guide to compare these animals and think about why they might have been such different sizes.

After working through the activity, have your students explore the Dinosaurs Under the Big Sky exhibit. Use the skeletons to make estimations and observations about the sizes of the dinosaurs on display. Using paces to estimate is fine. What are the largest and smallest dinosaurs on full display at the museum?
HOW BIG?

Classroom Instructions

**MATERIALS**

100’ Tape Measure, masking tape, any open area 100 feet long, dinosaur toys (optional) sidewalk chalk (optional)

**ACTIVITY TIME**

15-30 Minutes

**INSTRUCTIONS**

*This activity can be used as a math lesson and to support the sizes of dinosaurs, which can be an abstract concept for students.*

Providing a visual reference for the sizes of various dinosaurs can really help with the sense of scale of these extinct animals, some of whom grew to extraordinary sizes. Go out to a hallway or other open area and explain to your students that we will be measuring dinosaurs today. Establish a “starting line” or point from where the measurements will be starting.

First, have your students line up at the starting line. The first dinosaur we’re going to measure today will be Deinonychus, who was 12 feet long. Have students walk out to where they think 12 feet is. Then, measure it, see who was closest, and mark the spot with a piece of tape or a dinosaur toy.

Repeat the procedure for Triceratops (30 feet long), and Tyrannosaurus (45 feet long).

Lastly, tell them about Diplodocus, which is the longest dinosaur at Museum of the Rockies, and the longest type of dinosaur found in Montana. Diplodocus was a long-necked dinosaur about 90 feet long. Have students walk out to where they think 90 feet is, and then measure it again. High school basketball courts typically measure 84 feet long (though they can vary a bit in size). Next, we should divide the Diplodocus into thirds. The neck was about 30 feet long, the body another 30 feet, and the remainder is the tail. You can have students stand at each of these divisions to more clearly mark it. Note that the neck of the Diplodocus is just as long as a whole Triceratops!

You could also trace an outline of each of these dinosaurs on a basketball court, sidewalk, or other pavement.

For a math extension have students compare the lengths of each of these dinosaurs to each other, or measure and compare other large objects in the area, like cars, busses, trees, bridges, and so on.
How Big?

We’re familiar with the idea that dinosaurs were some of the largest creatures to walk the Earth, but just how big were they?

- **Argentinosaurus**: 70 tons or 140,000 pounds, 130 ft long
- **Diplodocus**: 15 tons or 30,000 pounds, 90 ft long
- **Triceratops**: 9 tons or 18,000 pounds, 30 ft long
- **Einiosaurus**: 1.3 tons or 2,600 lbs, 15 ft long
- **Deinonychus**: 0.08 tons or 160 lbs, 12 ft long
- **T. rex**: 9 tons or 18,000 pounds, 45 ft long
- **School Bus**: 18 tons or 36,000 lbs, 45 feet long
- **Gallon of Milk**: 0.004 tons or 8 lbs, ½ foot long
- **Average Adult**: 160 lbs, 5.5 feet long
- **Bison**: 0.7 tons or 1,400 lbs, 11 feet long
- **Elephant**: 7 tons or 14,000 lbs, 24 feet long
- **Boeing 737**: 38 tons or 76,000 lbs, 138 feet long
1. How many gallons of milk are equal to the weight of *Argentinosaurus*?

2. What modern object shown on the worksheet is closest in weight to *Triceratops*? *Einiosaurus*?

3. *Diplodocus* weighs about as much as _______ Elephants.

4. A Boeing 737 is about as long as which dinosaur?

5. How much longer is a *Tyrannosaurus* than a school bus?

6. How much longer is a *Triceratops* than a bison? How much heavier?
**How Big? (Cont.)**

*Troodon* and *Daspletosaurus* were two theropods who lived at the same time in Montana. Besides their sizes, they had a rather similar body structure, with two legs, two arms with sharp claws, a stout muscular head, and sharp teeth. What do you suppose these two animals ate?

What is one reason they might be different size animals?

What advantages do you think a small predator like *Troodon* had in its environment?

What advantages do you think a large predator like *Daspletosaurus* had in its environment?
How Big? (cont.)

Buff Or Slim?

Paleontologists have actually calculated a range of sizes for most dinosaurs. For instance, Tyrannosaurus is estimated to be between 7 tons and 12 tons. Why do you think paleontologists are unsure to what Tyrannosaurus’ true weight might have been?

More Modern Creatures

Can you think of a group of animals that have the same essential body structure, but are different sizes? List three examples here. Research one of your sets of animals, and find the largest and smallest members of that animal “family.”
How Big?

We’re familiar with the idea that dinosaurs were some of the largest creatures to walk the Earth, but just how big were they?

- **Argentinosaurus**: 70 tons or 140,000 pounds, 130 ft long
- **Diplodocus**: 15 tons or 30,000 pounds, 90 ft long
- **Triceratops**: 9 tons or 180,000 pounds, 30 ft long
- **T.rex**: 9 tons or 18,000 pounds, 45 ft long
- **Einiosaurus**: 1.3 tons or 2,600 lbs, 15 ft long
- **Deinonychus**: 0.08 tons or 160 lbs, 12 ft long
- **School Bus**: 18 tons or 36,000 lbs, 45 feet long
- **Gallon of Milk**: 0.004 tons or 8 lbs, ½ foot long
- **Average Adult**: 160 lbs, 5.5 feet long
- **Bison**: 0.7 tons or 1,400 lbs, 11 feet long
- **Boeing 737**: 38 tons or 76,000 lbs, 138 feet long
- **Elephant**: 7 tons or 14,000 lbs, 24 feet long
How Big? (Cont.)

1. How many gallons of milk are equal to the weight of Argentinosaurus?
   
   $\frac{140,000}{8} = 17,500$ gallons of milk

2. What modern object shown on the worksheet is closest in weight to Triceratops? Einiosaurus?
   
   Triceratops is closest to an elephant in weight.
   Einiosaurus is closest to a bison in weight.

3. Diplodocus weighs about as much as ___2___ Elephants.
   
   $\frac{15 \text{ tons}}{7 \text{ tons}} = 2.1$

4. A Boeing 737 is about as long as which dinosaur?
   
   Argentinosaurus

5. How much longer is a Tyrannosaurus than a school bus?
   
   They are about the same length.

6. How much longer is a Triceratops than a bison? How much heavier?
   
   Triceratops is 19 feet longer than a bison (or about 3 times as long).
   Triceratops weighs about 178,600 more pounds than a bison (or over 100 times heavier).
Troodon and Daspletosaurus were two theropods who lived at the same time in Montana. Besides their sizes, they had a rather similar body structure, with two legs, two arms with sharp claws, a stout muscular head, and sharp teeth. What do you suppose these two animals ate?

Meat because of their sharp teeth and claws.

What is one reason they might be different size animals?

Specialize in hunting different size mammals. Large predators eat larger prey and small predators eat smaller prey. Other reasonable answers may be correct.

What advantages do you think a small predator like Troodon had in its environment?

Smaller predators can be faster than larger predators. Smaller animals can more easily conceal themselves for hunting or defense.

What advantages do you think a large predator like Daspletosaurus had in its environment?

Large predators can attack large prey. Large predators can’t be attacked by smaller animals as easily, making it easier to defend a kill or scare away other predators from a kill.
How Big? (Cont.)

Buff Or Slim?

Paleontologists have actually calculated a range of sizes for most dinosaurs. For instance, *Tyrannosaurus* is estimated to have been between 7 tons and 12 tons. Why do you think paleontologists are unsure to what *Tyrannosaurus*’ true weight might have been?

All we have are their bones, and very few skin impressions. We can't be sure just how muscular or fat they may have been.

More Modern Creatures

Can you think of a group of animals that have the same essential body structure, but are different sizes? List three examples here. Research one of your sets of animals, and find the largest and smallest members of that animal “family.”

Dogs/Canines - Chihuahua, Labrador, St. Bernard

Cats/Felines - House Cat, Bobcat, Lion

Deer - Whitetail, Mule Deer, Elk

Whale - Beluga, Humpback, Blue Whale

Other appropriate and well thought answers are acceptable.
WHAT’S FOR DINNER?
Activity Overview

**BIG IDEA**
Dinosaurs (and other animals) have special tools that allow them to be successful carnivores, herbivores, and omnivores.

**OBJECTIVE**
Students will apply a basic understanding of “adaptation” to dinosaur food web interactions.

**BACKGROUND**
An adaptation is a special trait that allows a species to survive in its environment. There are all kinds of adaptations, but this activity focuses on how specific adaptations affect food web interactions. Not every dinosaur is equipped with meat shredding teeth, some have wide flat teeth that allow them to specialize in munching greens. Carnivores eat meat; herbivores eat plants; omnivores eat both plants and meat. Humans are omnivores, but some choose to be herbivores and only eat plant-based foods.

Dinosaurs (and other animals) have special tools that allow them to be successful carnivores, herbivores, and omnivores. Carnivores have sharp teeth and claws for tearing meat and typically move fast on two legs. Herbivores have flat teeth for grinding plants and typically move on all four legs to support their larger bodies; some herbivores have long necks for reaching tall trees while others have horns, tail spikes, or body armor for protection from carnivores. Omnivores don’t have as distinctive characteristics because their diet consists of both meat and plants. Most omnivores have sharp claws and a strong beak-like mouth that work well for tearing meat and cracking eggs or seeds; like carnivores, most move on two legs to run faster.

*Tenotosaurus* and *Deinonychus* Display
This *Tenotosaurus* is superbly preserved and nearly complete, with 11 teeth of the small meat-eater *Deinonychus* in close proximity. Previous *Tenontosaurus* excavations also yielded *Deinonychus* teeth, leading researchers to hypothesize a predator-prey relationship between the two animals.

Most toothed reptiles replaced their teeth on a regular basis throughout their life. *Deinonychus* replaced its teeth about every 300 days or so. Living toothed reptiles, like crocodiles, often lose their teeth when vigorously feeding. Eleven teeth is too many for one *Deinonychus* to
WHAT’S FOR DINNER?
Activity Overview

BACKGROUND

Lose while feeding on a carcass. Teeth replacement data suggests that it is likely that as many as six or eight *Deinonychus* fed on this *Tenontosaurus*. The discovery of this *Tenontosaurus* skeleton and affiliated *Deinonychus* teeth provides evidence for the suggestion the *Tenontosaurus* was killed and eaten by a group of *Deinonychus*!

*Triceratops* Pelvis Bitten by a *T. rex* Display

Studies of the puncture marks (red arrows) in this *T. rex* pelvic bone by former graduate student Greg Erickson determined that *T. rex* had bitten the bone with a bite force of 2,900 pounds, a force proportionately similar to the bite of a hyena. Note: The absence of any healing around the holes indicates that the *Triceratops* was dead before the punctures were made. There is no evidence to indicate that the *T. rex* killed the *Triceratops* – only that the *T. rex* ate the *Triceratops*. The bite marks on both the upper and undersides of the pelvis indicate that the body of the *Triceratops* had been completely torn apart, as the pelvic bone is normally deeply embedded in muscle.
WHAT’S FOR DINNER?
Museum Instructions

MATERIALS
Student activity sheets, clipboards, pencils (Pens, crayons, and markers are not allowed in exhibit spaces)

ACTIVITY TIME
45 Minutes

LOCATION
Start at the Tentontosaurs display in the Hall of Giants.

Deinonychus is the predator in this scene, while Tenontosaurus is the prey. In order for carnivores to survive, they must eat other animals. What adaptations did Deinonychus have that helped it survive? Deinonychus had sharp teeth and a strong jaw for ripping meat, and sharp claws for grabbing and tearing. Ask students what Tenontosaurus would eat. Point out the flat teeth and explain that flat teeth are used for grinding plant material.

Introduce the terms carnivore, herbivore, and omnivore to your students. Complete the first page of activity sheet and help your students find dinosaurs that are herbivores, carnivores, or omnivores by recognizing specific adaptations.

Then have your students investigate two specimens on display using the activity sheet. Help your students use the practices of science by asking questions and hypothesizing answers about these dinosaurs.

If time allows, explore the exhibit more, providing time for your students to determine whether various dinosaurs they find are herbivores, carnivores, or omnivores by recognizing specific adaptations.
WHAT’S FOR DINNER?
Classroom Instructions

MATERIALS
MOR Outreach Kits: Yellowstone Forest Ecosystem, images of the two dinosaur displays highlighted in this activity

ACTIVITY TIME
30 Minutes

INSTRUCTIONS
Tell your students that not all dinosaurs ate the same food, just like how not all animals today eat the same food. All animals have special teeth that help them chew their favorite foods. Introduce the terms carnivore, herbivore, and omnivore to your students. Complete the first page of activity sheet and help your students find dinosaurs that are herbivores, carnivores, or omnivores.

Use the modern mammal skulls in the Forest Ecosystem Outreach Kit to identify specific teeth adaptations of each of these types of animals.

Have your students investigate two specimens on display using the photographs of the displays provided. Help your students use the practices of science by asking questions and hypothesizing answers about these dinosaurs.

For example, in the first display, Deinonychus is the predator in this scene, while Tenontosaurus is the prey. In order for carnivores to survive, they must eat other animals. What adaptations did Deinonychus have that helped it survive? Deinonychus had sharp teeth and a strong jaw for ripping meat, and sharp claws for grabbing and tearing. Ask students what Tenontosaurus would eat. Point out the flat teeth and explain that flat teeth are used for grinding plant material.

As an extension, discuss with students how predator-prey interactions can influence the variation of traits in a species. It may be helpful to use modern animals for this discussion as well.
What’s for Dinner?

All living things need food to survive. Different dinosaurs have certain adaptations, or special traits, that allow them to better survive in their environment. Certain adaptations like tooth shape, claw shape, and location of eyes allow dinosaurs to be successful at catching their dinner or foraging for a snack.

Use the chart below to complete the activity.

<table>
<thead>
<tr>
<th>CARNIVORE</th>
<th>HERBIVORE</th>
<th>OMNIVORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Sharp teeth for</td>
<td>• Flat teeth for</td>
<td>• Beak-like mouths</td>
</tr>
<tr>
<td>__________</td>
<td>__________</td>
<td>• Mostly two-legged</td>
</tr>
<tr>
<td>• Two-Legged</td>
<td>• Four-legged</td>
<td>• Sharp claws</td>
</tr>
<tr>
<td>• Sharp Claws</td>
<td>• Some with horns, spikes, or other</td>
<td></td>
</tr>
<tr>
<td>• Excellent Vision and</td>
<td>body armor</td>
<td></td>
</tr>
<tr>
<td>Smell</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Draw or discover a Dinosaur that is an example of a carnivore

Draw or discover a Dinosaur that is an example of an herbivore

Draw or discover a Dinosaur that is an example of an omnivore

Carnivores are _______ eaters.

• Color the parts of your Carnivore that are adaptations for what it eats
• Draw something for your Carnivore to eat

Herbivores are _______ eaters.

• Color the parts of your herbivore that are adaptations for what it eats.
• Draw something for your herbivore to eat.

Omnivores are _______ eaters.

• Color the parts of your omnivore that are adaptations for what it eats.
• Draw something for your omnivore to eat

Are humans carnivores, herbivores, or omnivores?

Are omnivorous dinosaurs more like the carnivores or herbivores?
What’s for Dinner? (Cont.)

How do we know?

If you only look at body fossils, we can only infer what various dinosaurs ate. For instance, what modern animals have sharp teeth, sharp claws, and excellent senses of smell?

We can compare the anatomy of those animals to dinosaurs to infer what their behavior was. But for more direct fossil evidence, we have found the following fossils:

How many teeth are scattered around the dead dinosaur?

Did they come from the dead dinosaur?

Why are there so many?
What’s for Dinner? (Cont.)

How do we know?

Where on the body is the *Triceratops* bone?

How could you tell what kind of carnivore made those bite marks?
What’s for Dinner?

All living things need food to survive. Different dinosaurs have certain adaptations, or special traits, that allow them to better survive in their environment. Certain adaptations like tooth shape, claw shape, and location of eyes allow dinosaurs to be successful at catching their dinner or foraging for a snack.

Use the chart below to complete the activity.

<table>
<thead>
<tr>
<th>CARNIVORE</th>
<th>HERBIVORE</th>
<th>OMNIVORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Sharp teeth for <strong>Meat</strong></td>
<td>• Flat teeth for <strong>Plants</strong></td>
<td>• Beak-like mouths</td>
</tr>
<tr>
<td>• Two-Legged</td>
<td>• Four-legged</td>
<td>• Mostly two-legged</td>
</tr>
<tr>
<td>• Sharp Claws</td>
<td>• Some with horns, spikes, or other body armor</td>
<td>• Sharp claws</td>
</tr>
<tr>
<td>• Excellent Vision and Smell</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Draw or discover a Dinosaur that is an example of a carnivore

Draw or discover a Dinosaur that is an example of an herbivore

Draw or discover a Dinosaur that is an example of an omnivore

**Drawings will vary**

**Carnivores** are **Meat** eaters.

- Color the parts of your Carnivore that are adaptations for what it eats
- Draw something for your Carnivore to eat

**Herbivores** are **Plants** eaters.

- Color the parts of your herbivore that are adaptations for what it eats.
- Draw something for your herbivore to eat.

**Omnivores** are **Meat and Plants** eaters.

- Color the parts of your omnivore that are adaptations for what it eats.
- Draw something for your omnivore to eat.

Are humans carnivores, herbivores, or omnivores?

**Omnivores**

Are omnivorous dinosaurs more like the carnivores or herbivores?

**Carnivores**
What’s for Dinner? (Cont.)

How do we know?

If you only look at body fossils, we can only infer what various dinosaurs ate. For instance, what modern animals have sharp teeth, sharp claws, and excellent senses of smell?

Carnivores

We can compare the anatomy of those animals to dinosaurs to infer what their behavior was. But for more direct fossil evidence, we have found the following fossils:

How many teeth are scattered around the dead dinosaur?

11

Did they come from the dead dinosaur?

No

Why are there so many?

Six to eight Deinonychus may have fed on Tenontosaurus
What’s for Dinner? (Cont.)

How do we know?

Where on the body is the *Triceratops* bone?

**Pelvis**

How could you tell what kind of carnivore made those bite marks?

**Match the shape of the carnivore’s tooth to the bite marks**
MAIASAURA: GOOD MOTHER LIZARD

Activity Overview

BIG IDEA

*Maiasaura* is a duck-billed dinosaur whose name means “Good Mother Lizard.” Baby *Maiasaura* leg bones were too weak for a nestling to walk or run, so scientists hypothesize that adult *Maiasaura* cared for their young.

OBJECTIVE

Students will consider the basic needs of the *Maiasaura* and how it relied on its parents to survive the first year of its life.

BACKGROUND

In 1977, one of the world’s largest concentrations of dinosaur bones was discovered near Choteau in Teton County, Montana. The bonebed covers an area about one-half square mile and contains thousands of bones representing between 10,000 and 15,000 animals. The dominant dinosaur in this bonebed was a new hadrosaur species which was named *Maiasaura*.

In these areas, former Curator of Paleontology at MOR, Jack Horner and his team found the first clutches of dinosaur eggs from the Western Hemisphere and the first dinosaur embryos ever found in the world. They found clutches and embryos of both *Maiasaura* and *Troodon*, a small predator related to the *Velociraptor*. Babies were found within a *Maiasaura* nest and looked like they had been there for some time after they hatched. Undeveloped leg joints and trampled eggshells also indicated nestbound young not yet capable of leaving the nest. This fossil evidence led to the hypothesis that these dinosaurs cared for their young. Because of this evidence of parental behavior, the new dinosaur species was named *Maiasaura*, meaning “good mother reptile.”

*Maiasaura* grew very fast! At birth it was only 16 inches long and weighed about one and a half pounds, while an adult could be 30 feet long and weigh 4,000 pounds! After only one year, *Maiasaura* would be about 9 feet long!

The *Maiasaura* ("good mother reptile") is the state fossil of Montana and has not yet been found anywhere outside the state. *Maiasaura* was a medium-size, plant-eating hadrosaur (duck-billed dinosaur) which was about 26 feet long.
MAIASAURA: GOOD MOTHER LIZARD
Museum Instructions

MATERIALS
Student activity sheets, clipboards, pencils (Pens, crayons, and markers are not allowed in exhibit spaces), Book: *MAIA: A Dinosaur Grows Up*, by John R. Horner and James Gorman

ACTIVITY TIME
30 Minutes

LOCATION
Visit the Maiasaura and nesting section of the Dinosaurs Under the Big Sky Exhibit.

INSTRUCTIONS
Share with your students background information on Maiasaura and explore the exhibit, looking at the different nesting sites and all the Maiasaura fossils, including the embryo and nestlings. If time allows, read your students the storybook, *MAIA: A Dinosaur Grows Up*, by John R.Horner and James Gorman. (This book can be found in the Dinosaur Play Area next to the Viewing Lab.)

After learning about Maiasaura, looking at the displays, and reading the story, have your students complete the activity page.

When answering the questions in the activity, encourage students to use specific examples. Explain to students they may not know the exact answer to all of the questions, just like scientists don’t always have the exact answers. Ask students what they think scientists do when they don’t know the answer. Scientists make hypotheses; they use observations, evidence, and knowledge to come up with an explanation. Encourage students to be scientists and use their observations and knowledge to come up with hypotheses to answer the questions.
MAIASAURA: GOOD MOTHER LIZARD

Classroom Instructions

MATERIALS

Book: MAIA: A Dinosaur Grows Up, by John R. Horner and James Gorman

ACTIVITY TIME

30 Minutes

INSTRUCTIONS

Share with your students background information on Maiasaura. Read your students the storybook, MAIA: A Dinosaur Grows Up, by John R. Horner and James Gorman.

After learning about Maiasaura, looking at the displays, and reading the story, have your students complete the activity page.

When answering the questions in the activity, encourage students to use specific examples. Explain to students they may not know the exact answer to all of the questions, just like scientists don’t always have the exact answers. Ask students what they think scientists do when they don’t know the answer. Scientists make hypotheses; they use observations and knowledge to come up with an explanation. Encourage students to be scientists and use their observations and knowledge to come up with hypotheses to answer the questions.
Maiasaura is a duck-billed dinosaur whose name means “Good Mother Lizard.” Baby Maiasaurae were very small and their leg bones were too weak to walk or run. In order for their offspring to survive, the adult Maiasaurae cared for their young.

All living things need food, water, shelter, and space. If baby Maiasaura couldn’t walk, what would it depend on its mother for? Write or draw a picture of two things the baby Maiasaura would need from its mother.

Think of human babies. How do they depend on their parents? Write or draw a picture of two things a baby human needs from its mother.
**Maiasaura:**
Good Mother Lizard (Cont.)

What dangers might a baby *Maiasaura* need protection from? Write about or draw a danger baby *Maiasaura* might face.

To help protect their young, *Maiasaura* travelled in large herds with the young animals in the center of the herd. Draw a picture of herd of *Maiasaura* travelling with their young.
Maiasaura: Good Mother Lizard

Maiasaura is a duck-billed dinosaur whose name means “Good Mother Lizard.” Baby Maiasaurae were very small and their leg bones were too weak to walk or run. In order for their offspring to survive, the adult Maiasaurae cared for their young.

All living things need food, water, shelter, and space. If baby Maiasaura couldn’t walk, what would it depend on its mother for? Write or draw a picture of two things the baby Maiasaura would need from its mother.

Think of human babies. How do they depend on their parents? Write or draw a picture of two things a baby human needs from its mother.

Drawings could include food, water, or a nest

Drawings could include food, water, or a home
**Maiasaura**: Good Mother Lizard (Cont.)

What dangers might a baby *Maiasaura* need protection from? Write about or draw a danger baby *Maiasaura* might face.

Answers could include predators or weather

To help protect their young, *Maiasaura* travelled in large herds with the young animals in the center of the herd. Draw a picture of herd of *Maiasaura* travelling with their young.

Drawings will vary, but should include adult and juvenile *Maiasaura*
**TRICERATOPS GROWTH**

**Activity Overview**

**BIG IDEA**

*Triceratops*, like other dinosaurs, changed in appearance as they grew up. As babies, their horns pointed backward, then shifted as they grew older to point forward as they reached adult size.

**OBJECTIVE**

Students will learn that *Triceratops* horns changed as they grew up and that they used their horns and frills as a type of species recognition.

**BACKGROUND**

**What is a *Triceratops***?

Montana and Wyoming are famous for their horned (ceratopsian) dinosaurs. The first specimen of *Triceratops* was found in Wyoming, and since then many specimens of this horned dinosaur have been found in Montana, the Dakotas, Colorado and Saskatchewan. We have found two different horned dinosaurs from the Latest Cretaceous in Montana: *Triceratops* and *Montanaceratops*.

*Triceratops* lived from 68 to 66 million years ago in the northern Rocky Mountain region of North America and fed on plants. Based on collected fossils, we can say that *Triceratops* was one of the most common dinosaurs during the Cretaceous period. A full-grown adult *Triceratops* was about 26 feet long. The live animal would have weighed about 20,000 pounds (Note: A large bull elephant weighs about 14,000 pounds).

Museum of the Rockies has one of the largest collections of *Triceratops* fossils in the world including 100 skulls. The *Triceratops* had the largest skull of any known dinosaur. The MOR 1122 specimen in the exhibit’s *Triceratops* skull growth series is the largest dinosaur skull ever found. The skull is nine feet long and six feet wide. *Triceratops* had three horns, one called a nasal horn on the front of the skull, and one above each orbital (or eye socket) called orbital horns. Ceratopsians were the only dinosaurs to have had a rostrum which is a beak shaped bone located at the front of the mouth. Keratin does not fossilize but scientists believe that horns found as part of fossilized ceratopsian skulls are actually horn cores that would have been covered by a keratin sheath, just like horned animals today. Close study of horn cores indicates a hollow base.
**TRICERATOPS GROWTH**

**Activity Overview**

**BACKGROUND**

*Triceratops* Growth & Evolution

As *Triceratops* adults grew older, their faces got longer in proportion to their shields. Blood vessel grooves are more prominent than in the skulls of younger, smaller individuals. These grooves indicate that the keratin had hardened, and was pushing the vessels into the bone as the skull continued to grow.

The nasal bones and nasal horns of a large juvenile and small subadult *Triceratops*. Compare the unfused nasal bones of the large juvenile to the fused nasal bones of the small subadult. Fusion of the horn occurred sometime during the subadult stage when the skulls were around five feet long.

The bones of a mature adult *Triceratops* skull are tightly fused together and its orbital horns point completely forward, differently than those of the younger skulls. Note the shortness of the frill and the long facial region. Also notice the size of the nasal horn and the length of the rostrum anterior to the nasal horn. Compare these proportions with other *Triceratops* specimens. Young adult *Triceratops* have a short frill whereas a fully mature *Triceratops* has a long frill and a long face.
**TRICERATOPS GROWTH**

**Museum Instructions**

**MATERIALS**

Student activity sheets, clipboards, pencils (Pens, crayons, and markers are not allowed in exhibit spaces)

**ACTIVITY TIME**

30 Minutes

**LOCATION**

![Museum Floor Plan Image]

**INSTRUCTIONS**

Lead your group to the *Triceratops* growth series in the Hall of Horns and Teeth. Use the activity page to guide your students through an exploration of how *Triceratops* changed as it grew. Ask students to examine the fossils and casts on display to explore *Triceratops*. The background information provided can help you lead students and answer questions for this activity.

After completing the activity using *Triceratops*, explore other growth series on display and look for how those dinosaurs changed as they grew. Other displays include *T.rex, Maiasaura, and Diplodocus.*
**TRICERATOPS GROWTH**

*Classroom Instructions*

**MATERIALS**
Student activity sheets, pencils

**ACTIVITY TIME**
30 Minutes

**INSTRUCTIONS**
Use the activity page to guide your students through an exploration of how *Triceratops* changed as it grew. Ask students to examine the images on the activity sheet to explore *Triceratops*. The background information provided can help you lead students and answer questions for this activity.
How did *Triceratops* change in appearance as they grew?

First, number the skulls pictured below in order from youngest to oldest.

- 36 INCHES
- 18 INCHES
- 60 INCHES
- 24 INCHES

How were you able to tell which one was oldest? Or the youngest?
Triceratops Growth (Cont.)

Ontogeny

The study of how animals change as they grow is called Ontogeny.

Look back at the Triceratops photos on the front page. Besides the length (all animals grow up, after all), what is one difference in the shape of the skull as the Triceratops grew?

_________________________________________________________________
_________________________________________________________________

What is another difference in the shape of the skull as the Triceratops grew?
_________________________________________________________________
_________________________________________________________________

Think of another animal you know. Besides getting larger, do their heads change much as they grow up?
_________________________________________________________________
_________________________________________________________________
**Triceratops Growth**

How did *Triceratops* change in appearance as they grew?

First, number the skulls pictured below in order from youngest to oldest.

1. **36 INCHES**
2. **18 INCHES**
3. **60 INCHES**
4. **24 INCHES**

How were you able to tell which one was oldest? Or the youngest?

**By size**
Ontogeny

The study of how animals change as they grow is called Ontogeny.

Look back at the *Triceratops* photos on the front page. Besides the length (all animals grow up, after all), what is one difference in the shape of the skull as the *Triceratops* grew?

*Answers could include: size and direction of the horns, triangular pieces around the frill, size of the eyes, holes in the frill*

What is another difference in the shape of the skull as the Triceratops grew?

*See above*

Think of another animal you know. Besides getting larger, do their heads change much as they grow up?

*Typically an animal's skull and face will change, including the size of its eyes.*
RELATIVE VS. ABSOLUTE DATING

Activity Overview

The only way to know anything of the ecology of the past is because of the wide variety of fossils that have been found. People tend to think of all fossils as dinosaurs, but really fossils are any evidence of any past life, large or small, plant, animal, or even bacterial.

Students will explore the other kinds of fossils besides dinosaurs.

Paleontology combines geology and biology to study extinct organisms preserved in rocks. Knowledge of a wide variety of fossil types allows paleontologists to specialize in certain groups of organisms.

Paleontologists tend to specialize in a particular field of study, perhaps a particular type of animal. For instance they may specialize in ice-age mammals or the very first land animals. They may specialize in invertebrates or fish, and paleobotanists study ancient plants.

Micropaleontology works with fossils that can be found on a microscopic level, such as bacteria, fungal spores, pollen grains, or the tiniest shells and bones. A paleoecologist would study how all the different organisms of a time period interacted with each other. Paleoanthropologists study the most ancient of human fossils, but the study of ancient human cultures is actually archaeology, a branch of science that is often confused with paleontology.

A wide variety of fossils from every time era have been discovered in Montana. Some of the earliest ocean life is preserved in the Madison Group Limestone, which is a whitish-grey rock that forms many cliff faces in Western and Central Montana. Lewis and Clark Caverns is carved out of the Madison Limestone. Madison Limestone is from the oldest era - the Paleozoic.

Ammonites and Trilobites, have been persevered in Paleozoic formations, but are now extinct.
RELATIVE VS. ABSOLUTE DATING
Activity Overview (Cont.)

BACKGROUND (CONT.)

Plesiosaurs and small ratlike mammals lived at the same time as dinosaurs, however large mammals such as Woolly Mammoths, Woolly Rhinos, and Saber-toothed Cats became dominant long after the dinosaurs went extinct.
RELATIVE VS. ABSOLUTE DATING
Museum Instructions

MATERIALS
Student activity sheets, clipboards, pencils (Pens, crayons, and markers are not allowed in exhibit spaces)

ACTIVITY TIME
30 minutes

LOCATION

INSTRUCTIONS
This activity can be used to explore fossilization, paleo-ecology, and geologic time.

Most of the life forms described on the student worksheet can be found within the Landforms and Lifeforms and Dinosaurs Under the Big Sky Exhibits. To research each life form described, you will have to go through the entire exhibit to find them. The plant fossils are located near the end of the exhibit, past the Tyrant Kings section. Ice-Age Mammals can be found up the stairs near the Viewing Lab.

For students who have mobility needs, access to the ice-age mammals section can be accomplished through the third floor of the Children’s Discovery Center, which is accessible via elevator. Please ask Museum staff for assistance.

Dragonflies and grass fossils are not currently found in the exhibit. Students may be able to research these items on personal electronic devices, or teachers can share relevant information with your students from the Background Information section of this lesson. A description of where each life form is found in the geologic column can be found in the Background Information section of this lesson.
## RELATIVE VS. ABSOLUTE DATING

### Classroom Instructions

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Small 6 – 12 oz paper cups, or paper bowls for larger items</td>
<td></td>
</tr>
<tr>
<td>• Playdough (or equivalent)</td>
<td></td>
</tr>
<tr>
<td>• Plaster of Paris</td>
<td></td>
</tr>
<tr>
<td>• Water</td>
<td></td>
</tr>
<tr>
<td>• Mixing Bowl</td>
<td></td>
</tr>
<tr>
<td>• Stirring Stick</td>
<td></td>
</tr>
<tr>
<td>• Items to make a trace fossilization. Leaves work well, as do pine cones, feathers, small toys, or anything that you can make an impression into playdough. Students can go on a scavenger hunt near your school to find items, or can bring items from home. The item will not be destroyed.</td>
<td></td>
</tr>
</tbody>
</table>

### ACTIVITY TIME

45 minutes

### INSTRUCTIONS

This activity can be used to support lessons involving paleontology and fossilization. Providing a demonstration of how imprint fossils are formed can be helpful in understanding fossilization. We will use playdough and plaster to create an imprint fossil.

Place a bit of playdough in the bottom of a paper cup or bowl, and smush it in to fit the cup or bowl.

Next, take the item to be fossilized and press it into the playdough until you have an impression of the item.

Remove the item.

Mix plaster of paris and water in a ratio of about 2-1 in a mixing bowl, add more plaster or water as needed so that it is about the consistency of toothpaste.

Did you remove the item from the playdough? Pour the plaster of paris over the top of the playdough, so that the entire imprint is covered, with some extra.

Wait 24 - 48 hours until the plaster of paris is completely dry. Tear open the paper cup or bowl, and remove the playdough. What’s left will be an impression of your object, preserved in plaster.
RELATIVE VS. ABSOLUTE DATING
Classroom Instructions (Cont.)

If desired, the imprint can be stained with tea or coffee to look like a fossil, or painted.

With real imprint fossils, an object has been pressed into mud, and then covered with a different layer of mud. Usually this forms shale or slate, which then breaks apart into flat sheets, preserving the impression of a plant or part of an animal. An imprint fossil can also be found with a body fossil, such as when skin impressions are found with a dinosaur skeleton.
Relative vs. Absolute Dating

NAME ____________________________

Dinosaurs get a lot of our attention at the Museum of the Rockies, but in the “wild” you’re actually much more likely to find a fossil of something that is NOT a dinosaur! A fossil is evidence of past life, and that includes all life, such as sea animals, insects, mammals, and even plants.

There are two main types of fossils – body fossils and trace fossils. A body fossil is when the hard parts of the body of an animal or plant (such as wood or bones) is replaced and preserved by minerals or an impression of body or leaf is preserved. Trace fossils are fossils of things that animals did (such as nests or footprints). Impression fossils are impressions of parts of living things (such as leaves and skin impressions).

Research each fossil on the left, and match it with its correct location in the geologic time column on the right. Did it live before, after, or with the dinosaurs? Some organisms may have lived in more than one time period.
Relative vs. Absolute Dating

NAME ____________________________  ANSWER KEY

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<th>Time Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dragonfly</td>
<td>Paleozoic (P)</td>
</tr>
<tr>
<td>Trilobite</td>
<td>Paleozoic (P)</td>
</tr>
<tr>
<td>Plesiosaur</td>
<td>Paleozoic (P)</td>
</tr>
<tr>
<td>Ammonite</td>
<td>Mesozoic (M)</td>
</tr>
<tr>
<td>Fig Tree</td>
<td>Mesozoic (M)</td>
</tr>
<tr>
<td>Pine Cone</td>
<td>Mesozoic (M)</td>
</tr>
<tr>
<td>Belemnite</td>
<td>Mesozoic (M)</td>
</tr>
<tr>
<td>Wooly Mammoth</td>
<td>Cenozoic (C)</td>
</tr>
<tr>
<td>Cynodont</td>
<td>Cenozoic (C)</td>
</tr>
<tr>
<td>Wooly Rhino</td>
<td>Present</td>
</tr>
<tr>
<td>Saber-tooth Cat</td>
<td>Present</td>
</tr>
<tr>
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<td>Present</td>
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FOSSILS IN YOUR BACKYARD
Activity Overview

BIG IDEA

Millions of years ago, dinosaurs roamed all over our planet—Why is it then that we only find dinosaurs in certain geographical locations? These patterns can be explained by dating the rock formations on the surface of the Earth.

OBJECTIVE

Students will use the provided map to gain a sense of the variety of fossils found in their county.

BACKGROUND

Many of the rocks on or near the surface of Montana are from the time of the dinosaurs. Have students imagine what forces may bury or uncover layers of rock. Some forces that may expose fossils include large flood events, wind storms, earthquakes, volcanic events, and plate tectonics. Just because we don’t find dinosaurs in one area doesn’t necessarily mean that they didn’t live there at some point in time, it simply means that any evidence of their existence is still buried or may have already weathered away and disappeared. However, there are specific “ingredients” that need to be present in order for a fossil to form in the first place—See Making a Fossil.

This activity is an excellent introduction to MOR’s Dinosaurs Under the Big Sky exhibit. Fossils in your Backyard can be used as an extension to a lesson on plate tectonics and aligns well with the activity A Changing Landscape.
FOSSILS IN YOUR BACKYARD
Museum Instructions

MATERIALS
Student activity sheets, clipboards, pencils (Pens, crayons, and markers are not allowed in exhibit spaces)

ACTIVITY TIME
30 minutes

LOCATION

INSTRUCTIONS
This activity can be used to explore fossilization, erosion, and geologic time.

Montana is a very special place for fossils because it was an excellent location for deposition in the past, and it is a great location for erosion in the present. Deposition is the laying down of sedimentary rock layers, and typically only happens in wet climates, where many rivers flow, or in oceans and seas. Most fossils that have ever been found are actually from animals that lived in the water.

Erosion is the gradual wearing away of these sedimentary layers. As a sedimentary layer is eroded away, fossils can become exposed at the surface. After fossils are exposed, paleontologists can go collect them. It’s easier to find a location where fossils are already exposed, instead of just digging down in a random spot and hoping for the best!
A Geologic map shows you where different layers of rocks have been exposed by erosion. In some areas ancient rocks have been exposed, and in other areas the rocks are relatively newly deposited. To find dinosaurs, we must look in areas that have Mesozoic rocks that are exposed, since that is the time period in which dinosaurs lived. Work through the first page of the student’s activity page, identifying counties with Mesozoic rock layers.

For the second half of the Activity, have students plot the locations of ten dinosaur finds on the map. They can split up into groups and have each group taking a different section. The location each fossil was discovered at is mapped on the exhibit panels.

The location of some of Montana’s best known dinosaur dig sites deserve special mention and marking on the map as well:

Makoshika State Park is located to the east of Glendive in Dawson County.

Hell Creek is located north of Jordan, in Garfield County.

Egg Mountain is west of Choteau, in Teton County.

Rudyard Field Station is just west of Havre, in Hill County.
FOSSILS IN YOUR BACKYARD
Classroom Overview

MATERIALS
Sheets of felt (5-6 pieces); dinosaur or animal toys; images of eastern Montana MOR Outreach Kit: Fossils

ACTIVITY TIME
45 Minutes

INSTRUCTIONS
This activity can be used as a lesson regarding geologic time and fossilization. Tell the students that they will be exploring how organisms, specifically the bones of dinosaurs, become fossils.

Read the steps of fossilization (found in the Background Information from Activity 1 – MOR Fossils) to your students. Use felt and a plastic dinosaur, along with photos of eastern Montana, to provide a visual demonstration of fossilization while describing these steps. Alternatively, have your students read this description (printable handout in the Appendix).

Ask your students to look at the first two steps of fossilization – death and burial. Ask, what kind of climate did the dinosaurs now found in Montana live in? Students should describe a climate that is moisture-rich, that supported the plants some dinosaurs ate. This climate also supported the rivers, streams, and inland sea that provided sediment to bury some dinosaurs after their death. This was a time of deposition.

Now have your students look at the final two steps of fossilization – uplift, erosion, and discovery. Think about eastern Montana today. Ask, “What kind of climate is best for revealing and discovering fossils?” Students should describe an arid climate where erosion and weathering uncover fossils. While paleontologists worldwide can find dinosaurs in other climates, the arid environment of eastern Montana helps fossil discovery by making fossils easier to find on the earth’s surface.

Looking at the geologic map, point out that different amounts of erosion have happened at different places through Montana. That is why in some counties only Cenozoic rock formations – the most recent – are at the surface, and in some counties Archaean rock formations – the most ancient – are at the surface. Igneous (volcanic) rocks intrude into several different areas throughout Montana. No fossils can be found in igneous rock formations – why do students think that is?
Suppose several animals were found while prospecting for fossils – a dead antelope on the surface, a saber-toothed tiger just below the surface, and a few meters down some dinosaur bones. (You can demonstrate this by placing the animals in the appropriate layers of felt). Which animal died first? Last? How can they tell?
Fossils in your Backyard (Cont.)

Did you know that Montana is a great place to find fossils? That is because a lot of the rocks on or near the surface in Montana are from the age of the dinosaurs – the Mesozoic Era – from 245 to 66 million years ago. This special type of map is called a Geologic Map. It shows the type of rocks at or near the surface in Montana.

1. Shade all counties with Mesozoic rocks.

2. Find your county on the map and circle it.

3. Would you expect to find any dinosaur fossils in your county? (Are there any Mesozoic rocks in your county?)

4. Near what cities in Montana would you want to go to to look for dinosaur fossils?

Next, plot on the map the locations of dinosaur dig sites in Montana, which can be found on exhibit panels throughout the exhibit. Or, plot on the map four famous Montana dinosaur sites: Makoshika State Park, Hell Creek, Egg Mountain, and Rudyard Field Station.

Where might you travel if you wanted to find fossil mammals like wooly mammoths and saber-toothed cats?

Where might you travel if you wanted to find fossil evidence of the first life on earth?
Fossils in your Backyard (Cont.)

Did you know that Montana is a great place to find fossils? That is because a lot of the rocks on or near the surface in Montana are from the age of the dinosaurs – the Mesozoic Era – from 245 to 66 million years ago. This special type of map is called a Geologic Map. It shows the type of rocks at or near the surface in Montana.

1. Shade all counties with Mesozoic rocks.  
Any county with green should be shaded

2. Find your county on the map and circle it.  
Answers will vary

3. Would you expect to find any dinosaur fossils in your county? (Are there any Mesozoic rocks in your county?)

Answers will vary

4. Near what cities in Montana would you want to go to look for dinosaur fossils?

Answers will vary, but can include Cut Bank, Havre, Glasgow, Great Falls, Lewistown, Billings, and Glendive.

Next, plot on the map the locations of dinosaur dig sites in Montana, which can be found on exhibit panels throughout the exhibit. Or, plot on the map four famous Montana dinosaur sites: Makoshika State Park, Hell Creek, Egg Mountain, and Rudyard Field Station.

Where might you travel if you wanted to find fossil mammals like wooly mammoths and saber-toothed cats?

Any area shaded with yellow on this map.

Where might you travel if you wanted to find fossil evidence of the first life on earth?

Any area shaded with brown on this map.
This map is used with permission from the Montana Bureau of Mines and Geology.
HISTOLOGY
Activity Overview

BIG IDEA
Examining the microscopic structure inside of fossil bones show us that dinosaurs grew quickly.

OBJECTIVE
Students will learn that scientists can gain knowledge of how dinosaurs grew and behaved by studying the internal structure of their bones through paleohistology.

BACKGROUND
Histology is the study of the microscopic internal structure of bone, including hard and soft tissue. Scientists at Museum of the Rockies analyze thin bone slices to better understand dinosaur growth and behavior.

Histological evidence shows us that dinosaurs grew quickly, since many open channels, called vascular canals are present in the bones of the youngest animals. Animals that grow quickly typically have a high metabolism, which is an endothermic quality. The display panel includes cross-sectional histology images. The similarity between the ostrich and the Maiasaura tells us that dinosaurs, like birds, were endothermic heterotherms — animals that could vary their metabolic energy to maintain internal body temperature, and that could vary their metabolism and body temperature depending on conditions.

As a dinosaur matures, the inside of its bones will have rings similar to the inside of a tree. To determine the age of a dinosaur we analyze the number of rings. To figure out how long it took a dinosaur to grow up, we count the number of rings in the bones at different stages of growth—from hatchling all the way to adult animals. These rings are called ‘lines of arrested growth’ or ‘LAGs’.
HISTOLOGY
Museum Instructions

MATERIALS
Student activity sheets, clipboards, colored pencils (Pens, crayons, and markers are not allowed in exhibit spaces)

ACTIVITY TIME
20 Minutes

LOCATION
Take your students to the Mesozoic Media Center and have them explore the touch-screen computers. The photos (photomicrographs) in this hallway compare histology images and show microscopic clues in the structures of bones that can tell us whether an animal is warm or cold-blooded, how fast it grew, and how long it lived.

Did you know? MOR is the leader in dinosaur histology research—called paleohistology!

Explain to your students that bone histology is the study of the microscopic internal structure of bone. Scientists at the Museum of the Rockies analyze thin bone slices to better understand dinosaur growth and behavior. The insides of dinosaur bones have rings like the insides of trees, and to determine the age of a dinosaur we analyze the number of rings. To figure out how long it took a dinosaur to grow up, we count the number of rings, or Lines of Arrested Growth (LAGs), from hatchling size to adult size.
HISTOLOGY
Museum Instructions (Cont.)

In histological photomicrographs, you can also see open spaces in bones are the channels for blood vessels and nerves. The faster a bone grows, the more blood vessels must be present. Histological evidence shows us that dinosaurs grew quickly, since many of these channels are present in their bones. Animals that grow quickly typically have high metabolisms, which is an endothermic quality.

Using the activity sheet, have students compare the photomicrographs of the different growth stages of *Maiasaura*.

After completing the worksheet, visit the *Maiasaura* Growth Series in the Hallway of Growth and Behavior. There you can see the femurs from this histology series on display. Histology microscopic studies of the adult femur showed the *Maiasaura* rapidly grew from 11-in babies to 30-foot long adults in only seven years!
HISTOLOGY
Classroom Instructions

MATERIALS
Student activity sheets, optional: Mobile MAIA Science Lab from Carter County Museum

ACTIVITY TIME
20 Minutes

INSTRUCTIONS
Explain to your students that bone histology is the study of the microscopic internal structure of bone. Scientists at Museum of the Rockies analyze thin bone slices to better understand dinosaur growth and behavior. The insides of dinosaur bones have rings like the insides of trees, and to determine the age of a dinosaur we analyze the number of rings. To figure out how long it took a dinosaur to grow up, we count the number of rings, or Lines of Arrested Growth (LAGs), from hatchling size to adult size.

The photos (photomicrographs) show microscopic clues in the structures of bones that can tell us whether an animal is warm or cold-blooded, how fast it grew, and how long it lived.

Did you know? MOR is the leader in dinosaur histology research—called paleohistology!

In histological photomicrographs, you can also see open spaces in bones are the channels for blood vessels and nerves. The faster a bone grows, the more blood vessels must be present. Histological evidence shows us that dinosaurs grew quickly, since many of these channels are present in their bones. Animals that grow quickly typically have high metabolisms, which is an endothermic quality.

Using the activity sheet, have students compare the photomicrographs of the different growth stages of Maiasaura.

If available, after completing the worksheet, rent the Mobile MAIA Science Lab from Carter County Museum in Ekalaka, Montana, made in partnership with Museum of the Rockies. This lab includes casts of the femurs from this histology series. Use the lab as an extension to study dinosaur growth.

For more information about the Mobile MAIA Science Lab, please visit: http://cartercountymuseum.org/education/

Or call 406-775-6886
Histology

The inside of dinosaur bones have rings similar to the inside of trees. To determine the age of a dinosaur we analyze the number of rings, or Lines of Arrested Growth (LAGs).

Below are four images that show *Maiasaura* at different stages of growth. In these images, you can see open channels, called vascular canals, are present in the bones of the youngest *Maiasaura*. In the older *Maiasaura*, you can see the LAGs.
Write down a list of similarities and differences between the images. Discuss your findings with your classmates.

What do you think a histology image of your bone would look like? Why?
The inside of dinosaur bones have rings similar to the inside of trees. To determine the age of a dinosaur we analyze the number of rings, or Lines of Arrested Growth (LAGs).

Below are four images that show *Maiasaura* at different stages of growth. In these images, you can see open channels, called vascular canals, are present in the bones of the youngest *Maiasaura*. In the older *Maiasaura*, you can see the LAGs.
Write down a list of similarities and differences between the images. Discuss your findings with your classmates.

**Answers will vary**

What do you think a histology image of your bone would look like? Why?

*Elementary-age children would resemble a more compact version of the young juvenile, and the high school students would be most similar to the sub-adult dinosaur. Both young and mature humans would have spongy bone in the ends of their long bones.*
PEOPLE OF PALEONTOLOGY

Activity Overview

BIG IDEA
The field of paleontology has evolved over the years and continues to grow as more discoveries are made! The paleontologists highlighted on this activity are just a few of the many influential paleontologists throughout history and modern day.

OBJECTIVE
Students will explore different influential paleontologists and identify misconceptions about who can be a paleontologist or scientist.

BACKGROUND
A paleontologist is a scientist who studies fossils and ancient animals and plants.

The paleontologists featured in this activity are just a few of many scientists who have contributed to our knowledge of life on Earth. Remember, paleontologists don't only study dinosaurs, they also study fossilized plants and other living things from the past.

Included here are the paleontologists featured in this activity, along with the associated dates and a source to reference.

Mary Anning (1799-1847) was an English fossil hunter who started collecting fossils as a little girl and sold them to help support her family. She also found the first Plesiosaur and Ichthyosaurus.

For more information:

Benjamin Waterhouse Hawkins (1807-1894) made the first dinosaur models. He hosted a dinner party for some famous scientists inside his life-size model of an Iguanodon!

For more information:
PEOPLE OF PALEONTOLOGY
Activity Overview (Cont.)

BACKGROUND (CONT.)

Roy Chapman Andrews (1884-1960) was a fossil hunter and the director of the American Museum of Natural History. He led expeditions to the Gobi Desert where he discovered the first dinosaur eggs and many other new dinosaurs!

For more information:

Edward Drinker Cope (1840-1897) and Othniel C. Marsh (1831-1899) were both fossil hunters and good friends. As time passed, however, the two became more competitive with the number of fossils they discovered, and battled against each other in the “Bone Wars.” Over the course of their lifetimes, Cope found 56 new dinosaur species and Marsh discovered 80!

For more information:

Jack Horner (born 1946) was MOR’s Curator of Paleontology (1983 - 2016) and is best known for discovering the first dinosaur eggs in the Western Hemisphere and finding evidence that adult dinosaurs cared for their young. He is also the technical adviser for all of the Jurassic Park movies and is the inspiration for the lead character, Dr. Allan Grant.

EXTENSIONS

Have students work collaboratively or individually to write a report about a famous paleontologist and/or give a presentation as that paleontologist.

Read The Dinosaurs of Waterhouse Hawkins by Barbara Kerley and Brian Selznick.
PEOPLE OF PALEONTOLOGY
Museum Instructions

MATERIALS
Student activity sheets, clipboards, pencils (Pens, crayons, and markers are not allowed in exhibit spaces)

ACTIVITY TIME
30 Minutes

LOCATION

INSTRUCTIONS
Without much instruction, ask students to draw a picture of a paleontologist. Instruct students to include their tools and the environment in which they work. Students will complete the entire first page of the activity before discussion.

Once everyone has completed the first page, discuss with your students what paleontologists study – fossils of plants and animals.

Have your students read about, or listen to, brief descriptions of influential paleontologists included in this activity. Walk around the Dinosaurs Under the Big Sky exhibit and find names of the paleontologists that studied the fossils on display.

Using the second page, have your students describe any changes they would make to their picture of a paleontologist now that they have learned more. Have them describe what skills and knowledge they need to be a paleontologist. Finally help students distinguish between paleontology and archaeology. While paleontology studies fossils, archaeologists study human artifacts and remains.
PEOPLE OF PALEONTOLOGY
Classroom Instructions

MATERIALS
Student activity sheets and copies of People of Paleontology resource page

ACTIVITY TIME
20 Minutes

INSTRUCTIONS
Without much instruction, ask students to draw a picture of a paleontologist. Instruct students to include their tools and the environment in which they work. Students will complete the entire first page of the activity before discussion.

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As an extension, students can read more about the paleontologists highlighted in this activity or research other paleontologists.
People of Paleontology

Draw a picture of a paleontologist.

List three tools that paleontologists use.

1. _________________________________________________
2. _________________________________________________
3. _________________________________________________

Where do paleontologists work?
People of Paleontology (Cont.)

Listen to or read about paleontologists who made important discoveries.

Would you change anything in your sketch?

What skills do you need to be a paleontologist?

What about archaeologists? Though paleontology and archaeology are similar, they have a key difference. What is it?
People of Paleontology

1. Mary Anning (1799-1847)
   Anning was an English fossil hunter who started collecting fossils as a little girl and sold them to help support her family. She also found the first Plesiosaur and Ichthyosaurus.

2. Benjamin Waterhouse Hawkins (1807-1894)
   Hawkins made the first dinosaur models. He hosted a dinner party for some famous scientists inside his life-size model of an Iguanodon!

   Andrews was a fossil hunter and the director of the American Museum of Natural History. He led expeditions to the Gobi Desert where he discovered the first dinosaur eggs and many other new dinosaurs!

4. Edward Drinker Cope (1840-1897) and Othniel C. Marsh (1831-1899)
   Cope and Marsh were both fossil hunters and good friends, as time passed, however, the two became more competitive with the number of fossils they discovered, and battled against each other in the "Bone Wars." Over the course of their lifetimes, Cope found 56 new dinosaur species and Marsh discovered 80!

5. Jack Horner (born 1946)
   Horner was MOR’s Curator of Paleontology from 1986 to his retirement in 2016. He is best known for discovering the first dinosaur eggs in the Western Hemisphere and finding evidence that adult dinosaurs cared for their young. He is also the technical adviser for all of the Jurassic Park movies and is the inspiration for the lead character, Dr. Allan Grant.
People of Paleontology

Draw a picture of a paleontologist.

Drawings will vary

List three tools that paleontologists use.

1. ____________________________  Notebook

2. ____________________________  Rock Hammer

3. ____________________________  Other logical answers such as rulers, GPS, burlap, plaster, chisels, jackhammers

Where do paleontologists work?

Universities and dig sites
People of Paleontology (Cont.)

Listen to or read about paleontologists who made important discoveries.

Would you change anything in your sketch?

Answers will vary

What skills do you need to be a paleontologist?

Answers will vary

What about archaeologists? Though paleontology and archaeology are similar, they have a key difference. What is it?

Archaeologists study ancient people.

Paleontologists study ancient animals.