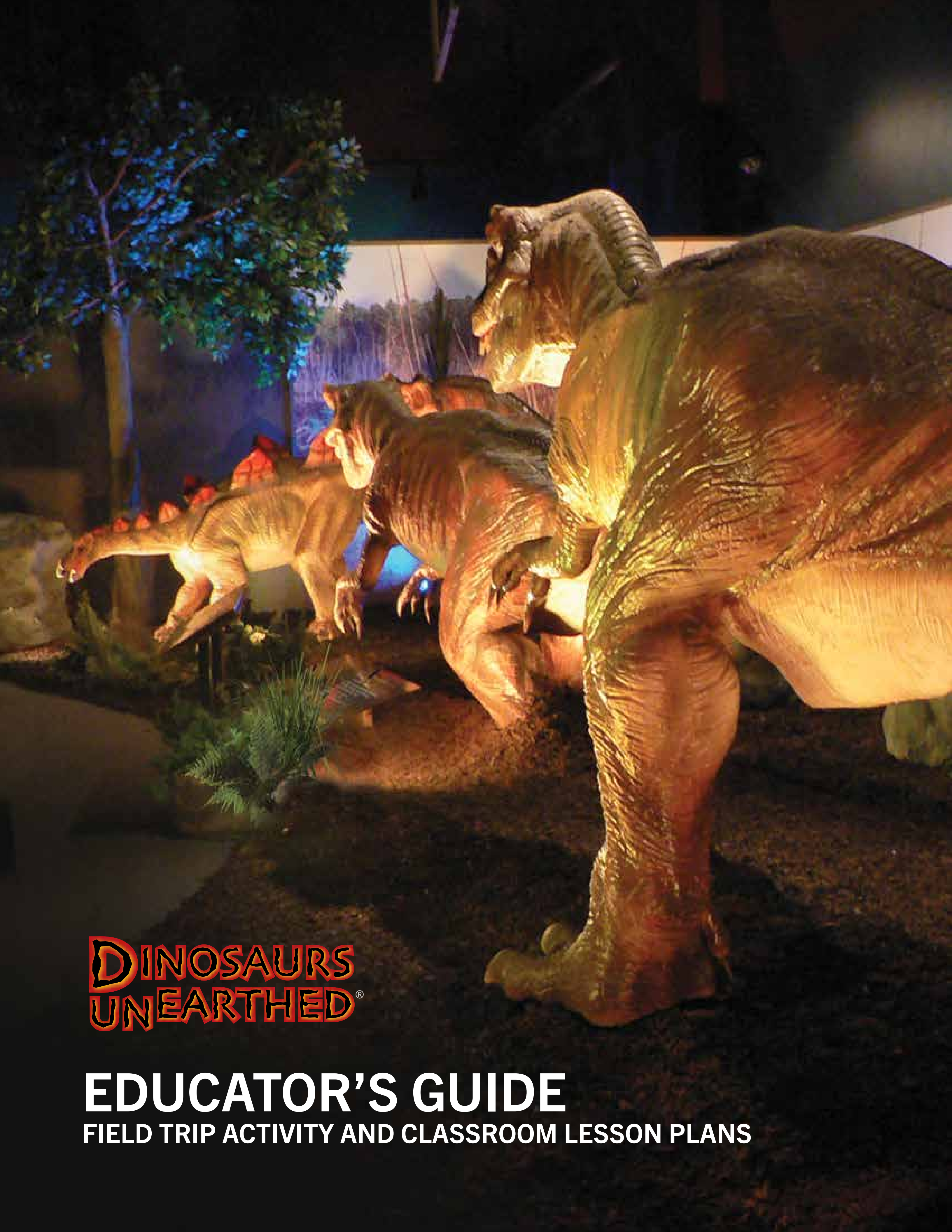
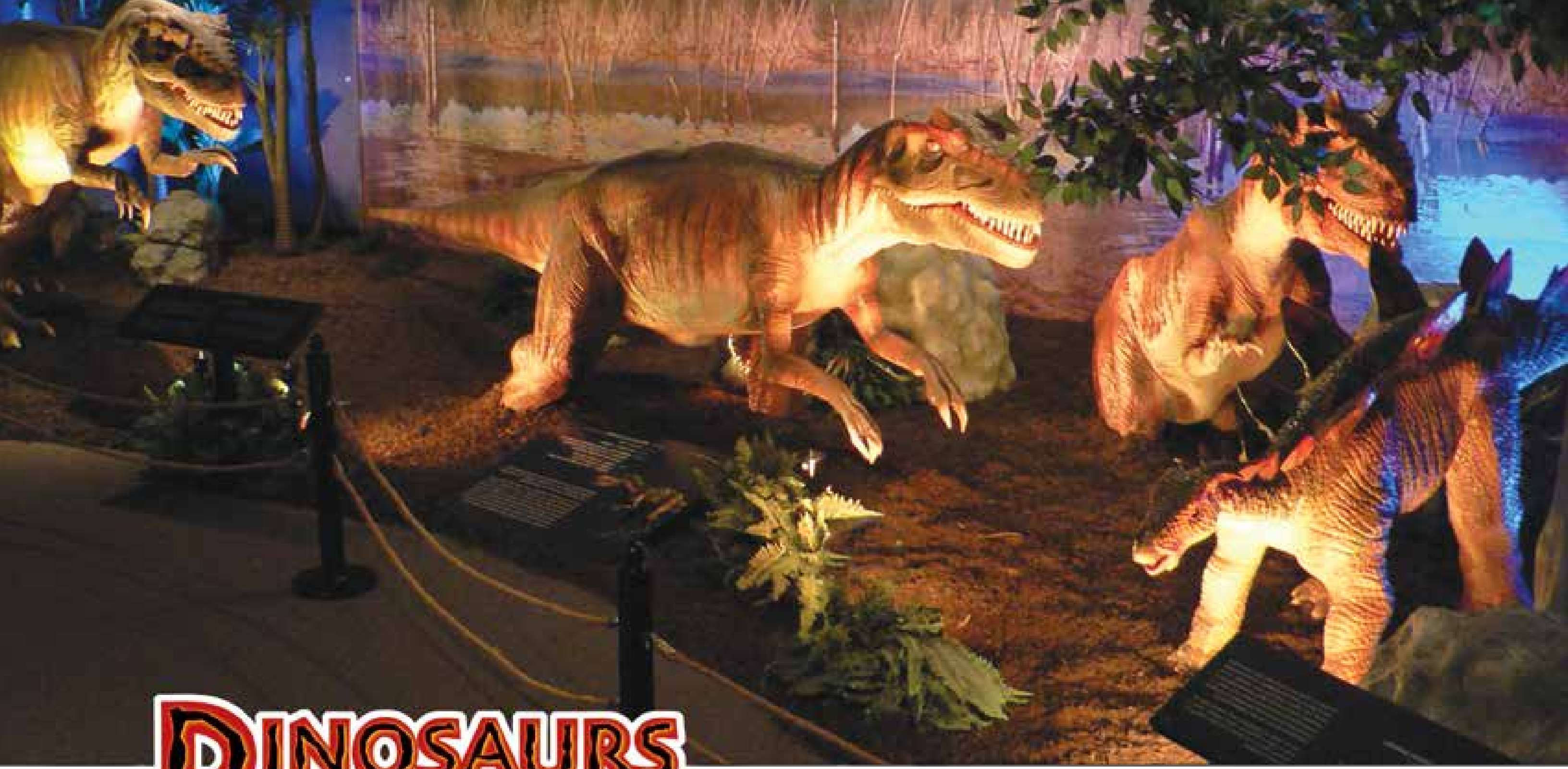


DINOSAURS UNEARTHED®

EDUCATOR'S GUIDE

FIELD TRIP ACTIVITY AND CLASSROOM LESSON PLANS



DINOSAURS UNEARTHED®

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DINOSAURS UNEARTHED

Content co-created by TurnKey Education, Inc. (2012) and Dinosaurs Unearthed (2015)

www.turnkeyeducation.net
www.dinosaursunearthed.com

INTRODUCTION

Welcome to DINOSAURS UNEARTHED!

The Field Trip

What is it about dinosaurs that capture our attention? This is an extremely complex question and the answers can be just as varied as the number of dinosaur species so far discovered. What is clear however is these long extinct inhabitants of ancient Earth are compelling in their diversity, their size, their behaviors, the length of time they dominated the planet and the reasons they suddenly died out.

Welcome to *Dinosaurs Unearthed*, the exhibition which reveals how the discovery of a single fossil led to the unearthing of a new species. The *Ruyangosaurus giganteous*, or Giant Ruyang Lizard, is the largest, heaviest sauropod found to date in Asia and its discovery changed a village and challenged long held cultural beliefs. Follow the fossil evidence of the famous predator trap at the Cleveland-Lloyd Quarry in Utah in order to understand the predatory behaviors of *Allosaurus*. Travel from the interconnecting rivers and mud flats of the *Allosaurus* territory to the blistering sand dunes of Mongolia where one of the

few instances of dinosaurs engaged in combat has been preserved in the fossil record. *Velociraptor* versus *Protoceratops* captures that moment just before battle and showcases one of the latest paleontological discoveries – that some dinosaurs were feathered!

The discovery of feathers and dinosaurs continues with a new look at one of North American's most iconic dinosaurs, *Tyrannosaurus rex*. Covered with a coat of protofeathers which helped to regulate body temperature in the younger, smaller tyrannosaurid, the juvenile *T. rex* contrasts sharply in appearance with the life-size adult. Even without feathers there are differences between juveniles and adults. A life-size *Triceratops* adult and juvenile vividly shows the differences between the growth stages. The familiar forward jutting brow horns in the adult are only small, backwards curving versions in the juvenile while the nose horn is a much shorter snub. A juvenile *Triceratops* is not just a miniature representation of an adult.

Combining finely detailed, hand-crafted animatronics, fossils, skeletons, interactive consoles and educational content that reflects the latest scientific theories, *Dinosaurs Unearthed* offers not only the excitement of a tail thrashing, clawing and roaring Field Trip but is a unique learning opportunity to update your dinosaur knowledge in a never to be forgotten experience.

The Educator's Guide

This Educator's Guide has been created to help teachers and students make the most of their Field Trip to *Dinosaurs Unearthed*. In this guide there are six Classroom Lesson Plans based on STEM criteria centered on key topics highlighted in the exhibition.

These Lesson Plans contain dynamic activities and assignments geared towards elementary school students as well as adaptations and advanced lessons for older grades. The guide is created to be flexible; use it to best fit the needs and capabilities of your class. You may select some of the lower level activities for use with your eighth graders or you might pull from some of the more advanced activities for use with your most curious and sophisticated young paleontologists.

The guide also contains recommended reading lists to expand your students' knowledge of the world of dinosaurs, plus dinosaur-themed games and puzzles for both younger and older students and dinosaur fun facts. We know how important it is to be able to justify field trips and document how instructional time is spent outside your classroom. To that end, the Educator's Guide is directly correlated to national curriculum standards.

These resources can be used before your visit to prepare students for the teachable moments found throughout the exhibition as well as when you return to school to further explore the connections between the educational themes of the exhibition and your classroom instruction. Take advantage of this unique opportunity to bring science to life for your students.

The Educator's Guide which accompanies the Field Trip was developed by an award winning educational consultant to meet curriculum standards and enhance your school's visit. We look forward to seeing you at *Dinosaurs Unearthed*.

LESSON 1: FORM AND FUNCTION

At the exhibition you will see how dinosaurs adapted based on their needs, environments and diets. In the classroom, your students learn about some of the anatomical differences between predators and prey while doing a hands-on experiment on depth perception.

LESSON 2: DINOSAUR DETECTIVES

Students research paleontologists and their discoveries and learn first-hand that science is a dynamic and ever-changing world. While at the exhibition, your students will see the culmination of over a hundred years of paleontology.

LESSON 3: MESOZOIC MATH

Students work with measurements, proportions and scale models of the true-to-life size dinosaurs they see on their field trip.

LESSON 4: FEATHERED FRIENDS

At *Dinosaurs Unearthed*, you learn about feathered dinosaurs and their connections to the living birds of today. In the classroom, younger students examine the feathers that both birds and dinosaurs need to fly, while older students prepare for a mock trial to prove that modern day birds are in fact the descendants of dinosaurs.

LESSON 5: FINDING FOSSILS

Demonstrates the complexities involved in identifying and reconstructing dinosaur skeletons – like those at the exhibition – based on rare and incomplete fossil evidence.

LESSON 6: TRACES OF DINOSAURS

Students determine the best conditions for preserving dinosaur footprints while extrapolating knowledge about how dinosaurs behaved from trace fossils like trackways and coprolites.

FIELD TRIP ACTIVITY Name Class Date

WHO AM I?

Read the clues and look for these creatures on your field trip to *Dinosaurs Unearthed*. Fill in the first column with the dinosaurs' names as you encounter them; then answer the questions following the chart.

	WHO AM I?	MY UNIQUE FACT	I LIVED IN THE	THE AREA I LIVED IN WAS
1.		As a very young juvenile, the horns were much smaller buds.	Late Cretaceous 65 Mya	North America: USA – Colorado, Montana, South Dakota, Wyoming; Canada – Alberta, Saskatchewan
2.		I was an agile, multi-directional runner unlike the adults of my species.	Late Jurassic 150 Mya	North America: USA – Montana, Kansas, North Dakota, South Dakota, Nebraska, Wyoming, Colorado; Europe: Portugal
3.		As a juvenile I was no match for Allosaurus but as an adult I had a mean tail weapon.	Late Jurassic 150 Mya	North America: USA – Montana, Kansas, North Dakota, South Dakota, Nebraska, Wyoming, Colorado; Europe: Portugal
4.		I am one of the first horned-face dinosaurs.	Late Cretaceous 75 Mya	Asia: Mongolia – Gobi Desert
5.		I am the largest Cretaceous sauropod yet discovered in Asia.	Late Cretaceous 99.6 - 89.3 Mya	Asia: China – Henan Province
6.		I am the largest Asian Late Jurassic predator yet found.	Late Jurassic 160 Mya	Asia: China – Sichuan Province
7.		In 2007 it was revealed that my forelimbs had quill knobs.	Late Cretaceous 75 Mya	Asia: Mongolia – Gobi Desert
8.		A four-winged glider, I may look like a bird but I am a theropod.	Early Cretaceous 125 Mya	Asia: China – Liaoning Province
9.		Recent research shows that I had a coat of fine, downy feathers until I grew to be a sub-adult.	Late Cretaceous 65 Mya	North America: USA – Colorado, Montana, New Mexico, Wyoming; Canada – Alberta

Name Class Date

10. The dinosaur in the illustration to the right is in the *Dinosaurs Unearthed* exhibition. It was one of the first ceratopsids or horned-face dinosaurs. What is its name?

11. Which time period has the most dinosaurs on the chart?

12. Which three US states would be the best for fossil hunting? (Hint: Which three states are on the chart the most?)

13. Which province in Canada would be best for fossil hunting?

14. Once you complete the Field Trip Activity "Who Am I?" chart, place the dinosaurs in order starting from the earliest (Late Jurassic) to the latest (Late Cretaceous) showing the name, time period and date.

LESSON 1: FORM AND FUNCTION

How do the scientists and engineers behind the scenes at *Dinosaurs Unearthed* know how to accurately create the moving, roaring, life-size beasts you see on your field trip? They study and learn from the evidence the real dinosaurs left behind, like fossilized bones.

Prey animals (like the juvenile *Ruyangosaurus*) usually have eyes spaced far apart and on the sides of their heads, while the eyes of a predator (like *Allosaurus* or *Tyrannosaurus rex)* face forward so they can focus on what's in front of them – a tasty dinner!

Animals that are prey, meaning that they are hunted by other animals, need eyes that can see all around them in order to be able to watch out for danger. Predators are animals that hunt, kill and eat other animals. They need eyes that give them good depth perception and the best chance of catching their prey.

Activity 1: Elementary School (Grades K - 5)

How are mice and cats like dinosaurs? It's all in the eyes. Animals that hunt for food need to have a good aim, good hand-eye (or hand-claw) skills and good depth perception. When our brain tells us what we are seeing, it needs information from both eyes. For depth perception, the brain uses the differences between the picture from the left eye and the picture from the right to figure out how far away something is.

When only one eye sends information, the picture is not complete and depth perception is lost. Imagine how hard it would be to hit a baseball if you couldn't tell whether the pitcher stood 16 feet away or 60 feet.

The biggest carnivorous hunters were the theropods, like Tyrannosaurus rex, *with forward-facing eyes.*

Name Class Date

When the eyes are close together on the front of the head, an animal has what is called “binocular vision” and better depth perception. This means it is easier for them to tell how far something – like their dinner – is from them. This activity will show you how animals with binocular vision, including humans and dinosaurs, have better depth perception when both eyes are looking at the same object at the same time.

Materials

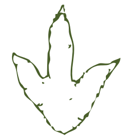
- Partner
- Pencil or pipe cleaner
- Washer with a hole larger than pencil/pipe cleaner diameter
- Modeling clay
- Eye patch

Procedure

1. Stand the washer up on the clay.
2. Turn the clay and washer so that you are looking at the side of the washer – not the hole.
3. Hold the clay and washer in one hand with that arm stretched out in front of you.
4. Put the eye patch on one eye.
5. Try to put the pencil or pipe cleaner through the washer, like threading a needle.
6. Repeat the experiment so that you make 10 tries with the right eye covered, 10 tries with the left eye covered, and 10 tries with both eyes open.
7. Your partner will count your tries and record your results in this chart.

	Right eye covered, left open		Left eye covered, right open		Both eyes open	
	yes	*no*	*yes*	*no*	*yes*	*no*
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

What happened?



One of the most intelligent dinosaurs was *Troodon*. It had a brain the same size as a mammal or bird of today, plus binocular vision, and grasping hands.

1. How many times were you able to put the pencil or pipe cleaner through the washer with…

   only your left eye open? ______________________________

   only your right eye open? ______________________________

   both eyes open? ______________________________

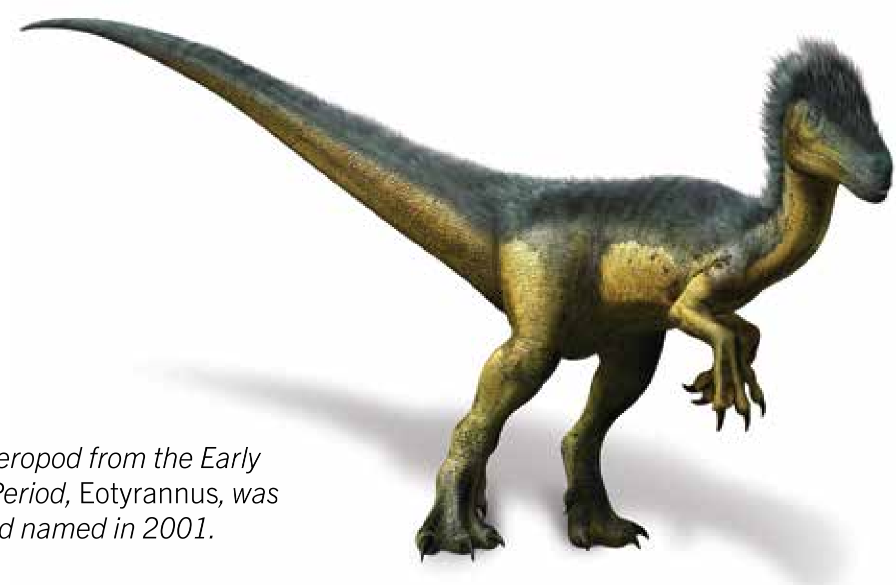
2. Would you be a good predator, like the *Eotyrannus* below, if you could only see with one eye at a time? Why or why not?

   ____

   ____

Try it!

- Calculate your success rates in number 1 above by dividing each total number by 10, then multiplying by 100 for a percentage. For example, if you were successful with only your left eye four times: 4 ÷ 10 X 100 = 40%.
- For your next science fair project, test your classmates and family to "see" if being right-handed or left-handed connects to whether they can thread the washer better with one eye or the other.
- Repeat the experiment on a larger scale. Have your partner toss you a bean bag or soft ball 10 times and see how well you can catch it with only one eye.



This small theropod from the Early Cretaceous Period, Eotyrannus, *was described and named in 2001.*

Activity 2: Middle and High School (Grades 6 - 12)

Eye position is only one of the things paleontologists study in order to learn more about a dinosaur. A dinosaur's teeth, if there are any left, can tell us if that creature was an herbivore or a carnivore. When we see armored plates we know that this was an animal that needed protection from neighbors with sharp teeth! What makes dinosaurs look so strange to us are exactly what helped the species survive, even if all those frills, knobs, crests, and horns were only there to make a dinosaur as handsome as possible to find a mate.

In this activity, match the features of a "mystery" dinosaur in the first list with the conclusions that can be made about that dinosaur's identity and life in the second list. The first one has been done for you.

Observations

1.	K	*Allosaurus* teeth marks on vertebra	7.		No tail marks found in trackways
2.		Eyes on the sides of its head	8.		No fossils in what would have been water
3.		Four large legs, footprints far apart	9.		About 150 million years old
4.		Gastroliths	10.		Dull, straight, rake-like teeth
5.		Hollow backbones	11.		Heart and brain separated by a long neck
6.		Long neck didn't lift above horizontal	12.		Long ribs and stout leg bones

Conclusions: This dinosaur…

A. was an herbivore.
B. didn't live in a jungle or forest because it would constantly hit trees and get stuck.
C. needed light-weight bones.
D. held its tail up in the air, off the ground.
E. was not a predator.
F. lived in the Jurassic Period.
G. moved slowly.
H. needed a large, strong heart to keep enough blood pumping to the brain.
I. was a heavy animal with a large torso.
J. needed help digesting plant fibers.
K. was hunted by *Allosaurus*.
L. was not a swimmer.

13. Based on this information, what dinosaur do you think it is? ______________________________

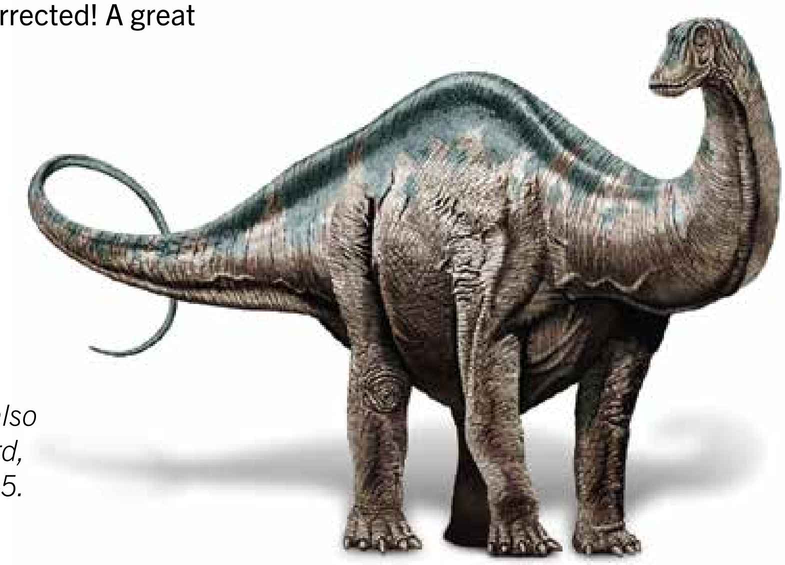
LESSON 2: DINOSAUR DETECTIVES

"Dinosaur detectives" (better known as paleontologists) are always learning new information about the prehistoric creatures you will see on your field trip to *Dinosaurs Unearthed.* Sometimes they even update past assumptions which radically alter what we thought we knew about dinosaurs.

When *Stegosaurus* was first discovered in the late 1800s, the famous paleontologist Othniel C. Marsh thought it might have had a second brain in a small space near the base of its tail. When a *Triceratops* was discovered, scientists first classified it as something similar to a buffalo, not a dinosaur.

Research sometimes causes dinosaur names to go extinct. But they can also be resurrected! A great example is what happened to *Brontosaurus*. A sauropod specimen found in 1879 was originally named *Brontosaurus excelsus* but was re-examined in 1903 and thought at the time to be a larger specimen of the earlier named *Apatosaurus*. In the 1980s, other museum mounted skeletons of "*Brontosaurus*" were discovered to be a combination of an *Apatosaurus* body and *Camarasaurus* head.

Brontosaurus was taken out of the dinosaur lexicon for a few decades but a new examination of the bones in 2015 revealed that *Brontosaurus excelsus* was in fact a distinct and separate species. The name has come back into use - much to the delight of many.



The name Brontosaurus, *also known as the thunder lizard, came back into use in 2015.*

Activity 1: Elementary School (Grades K - 5)

The paleontologists listed in the chart on the next page are just 10 of the dozens of early scientists who first studied dinosaurs. Some of the conclusions reached by the early reseachers have since been refuted but their groundwork laid the foundations for the scientific study of dinosaurs.

In the chart, fill in the paleontologists' dates, nationalities, and the name of one of the dinosaurs they named. One has been done for you. Then, answer the questions that follow.

Name Class Date

Name	Birth-Death	Nationality	Dinosaur Named
Roy C. Andrews			
Barnum Brown			
William Buckland			
Edward D. Cope			
Lawrence M. Lambe			
Joseph Leidy			
Gideon Mantell			
Othniel C. Marsh			
Henry F. Osborn			
Hermann von Meyer	1801-1869	German	*Archaeopteryx*

The first dinosaur to be officially named was *Megalosaurus*, in 1824 by the Reverend William Buckland.

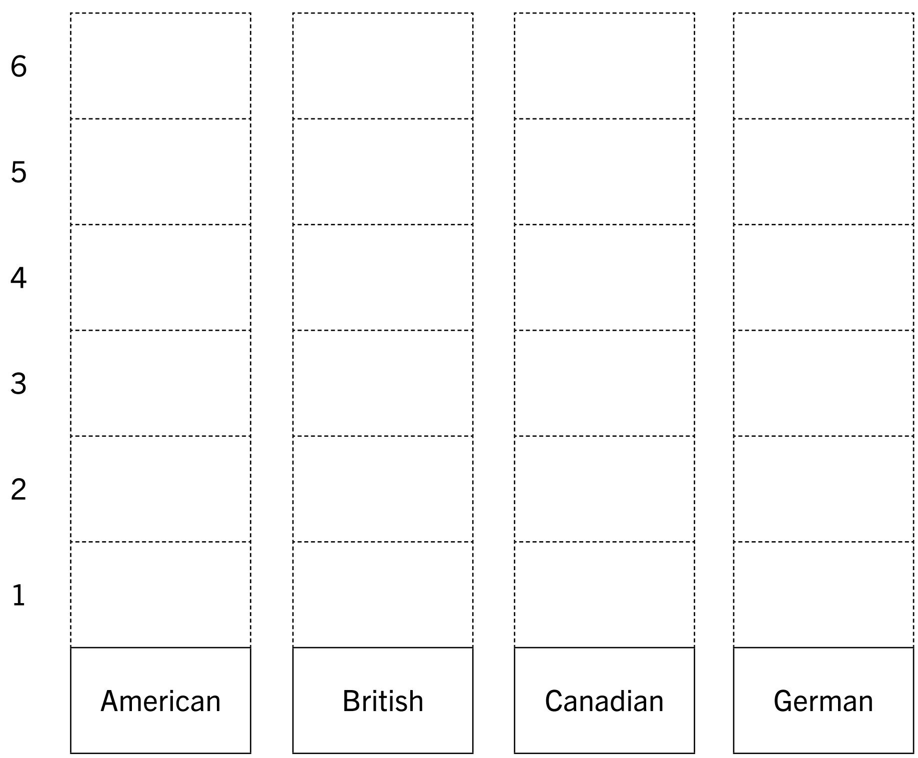
Name Class Date

1. Which paleontologist in the chart was born first? In what year? ______________________

2. Which nationality appears the most? ______________________

3. What reason do you think would explain this? ______________________

4. Color in the bar graph to show the number of paleontologists on the chart from each country.



Name Class Date

Activity 2: Elementary School (Grades K - 5)

Dinosaurs may be long gone, but new fossil discoveries and new theories from today's dinosaur detectives keep them in the spotlight! Working in groups and using the most recent dinosaur news found on the sites provided below, write, create and produce a "Breaking News" dinosaur newscast. Produce a YouTube video of your report and post it on your school website.

- Dinosaur News:
  http://www.dinosaurnews.org/
- *Laelaps:*
  https://blogs.scientificamerican.com/laelaps/
- *Archosaur Musings* Dinosaur Blog:
  http://archosaurmusings.wordpress.com/

Activity 3: Middle and High School (Grades 6 - 12)

Not everyone who has a career working with dinosaurs is a paleontologist! Research these four people. Identify their careers and how they contributed to our knowledge of dinosaurs.

1. Luis Alvarez ____________________
2. Benjamin W. Hawkins ____________________
3. Arthur Holmes ____________________
4. Alfred L. Wegener ____________________

Creating intricate, life-size dinosaurs requires teams of experts. Writers, animatronic engineers, graphic designers, artists, landscapers, lighting experts and exhibition designers all helped create these animatronic masterpieces and the settings they inhabit. What other careers are part of discovering, studying, constructing, displaying and touring dinosaurs? Brainstorm a list of possibilities. Create a Dinosaur Job Fair in your class. Identify job titles, the education required, colleges and universities with the appropriate course of study, pay rate and duties and responsibilities. Could this be your future career?

Production crew sets up a T. rex

LESSON 3: MESOZOIC MATH

Since humans were not alive 65 million years ago, no one knows for sure exactly how long, tall, heavy or fast dinosaurs really were. Scientists come to conclusions based on many pieces of information including studying and measuring the size of fossils. Exhibition designers use that data to create the life-size models you see on your field trip to *Dinosaurs Unearthed*.

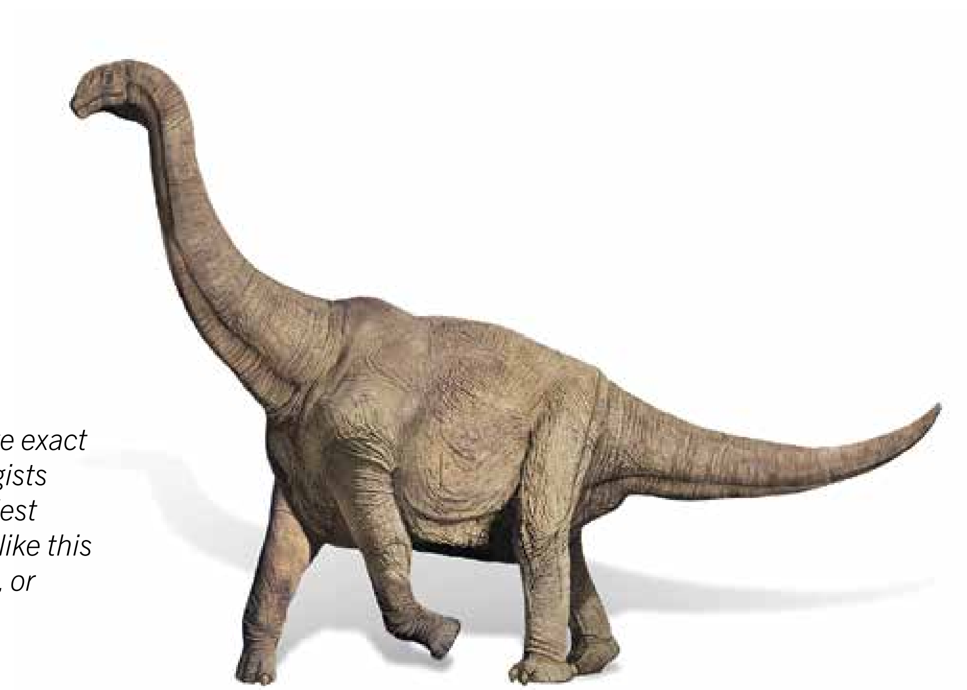
But how do we know if a fossil came from a particularly small or big version of that kind of dinosaur? The more fossils that are discovered, the closer we get to figuring out the real lengths, heights, and weights of these extinct creatures.

In this lesson, you will compare dinosaurs from different time periods, using average lengths from scientists' best guesses, and then use those measurements to create your own exhibition of dinosaurs!

One of the smallest dinosaurs to be discovered, so far, was only slightly larger than a modern-day chicken. *Compsognathus* grew to be about 3 feet long and weighed only about 6½ pounds.

Activity 1: Elementary School (Grades K - 5)

The dinosaur chart has information on 10 dinosaurs. For each dinosaur, the length is listed in both meters (m) and feet (ft). Study the chart to answer the questions that follow.



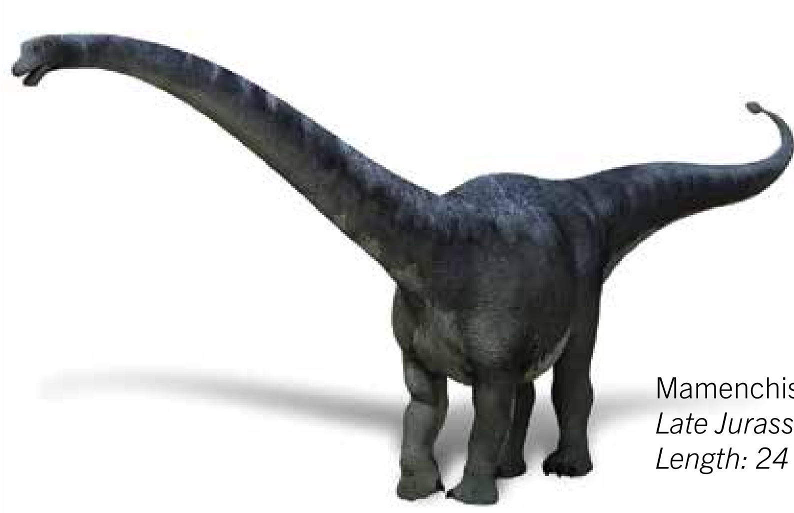
Although we may never have exact measurements, paleontologists are confident that the heaviest dinosaurs were sauropods, like this Ruyangosaurus giganteous*, or "*Giant Ruyang Lizard.*"*

Name Class Date

DINOSAUR CHART - TIME PERIOD AND LENGTH

Name	Period	Length	
Allosaurus	Late Jurassic	12 m	39.6 ft
Apatosaurus	Late Jurassic	23 m	75.9 ft
Baryonyx	Early Cretaceous	9 m	29.7 ft
Huayangosaurus	Mid-Jurassic	4 m	13.2 ft
Mamenchisaurus	Late Jurassic	24 m	79.2 ft
Omeisaurus	Late Jurassic	20 m	66.0 ft
Parasaurolophus	Late Cretaceous	9 m	29.7 ft
Stegosaurus	Late Jurassic	9 m	29.7 ft
Triceratops	Late Cretaceous	9 m	29.7 ft
Tyrannosaurus rex	Late Cretaceous	13 m	42.9 ft

Name Class Date



Mamenchisaurus
Late Jurassic
Length: 24 m (79.2 ft)

Reading the Chart

1. Which dinosaur was from the Early Cretaceous Period?

2. Which four dinosaurs had the same length?

3. Which dinosaur was longer, *Allosaurus* or *Tyrannosaurus rex*?

Length

4. If all these dinosaurs stood head-to-tail, how long would the line be?

    a. In meters: ______________________

    b. In feet: ______________________

Not every sauropod was a behemoth like *Argentinosaurus* (up to 36 meters/118 feet) or had an incredibly long neck like *Mamenchisaurus*. *Magyarosaurus*, which was discovered in Romania in 2005, was "small" and measured only 5.3 meters/17 feet long.

Name Class Date

5. *Huayangosaurus* (4 m/13.2 ft) is the shortest dinosaur on the chart and *Mamenchisaurus* (24 m/79.2 ft) is the longest. How many *Huayangosaurus* would fit in one *Mamenchisaurus*? Show your work.

6. Here are two ways to see how the dinosaurs' sizes compared to each other and how they would have looked in real life!

   a. When we study something very large, like a dinosaur, it is easier to work on a smaller version called a scale model. In the chart above, let's pretend that the meters are actually centimeters. On a piece of paper, measure and draw a line for each dinosaur based on these new versions of their length. For example, *Apatosaurus* is 23 meters; draw a line on your paper that is 23 centimeters long and label it "*Apatosaurus*."

   b. Divide your class into 10 groups and assign a dinosaur from the chart to each group. Go outside, in the hallway, or into the gym with long ropes and measuring tapes or meter sticks. Each group measures and marks off the length of their dinosaurs using the rope to see how long that dinosaur would really be.

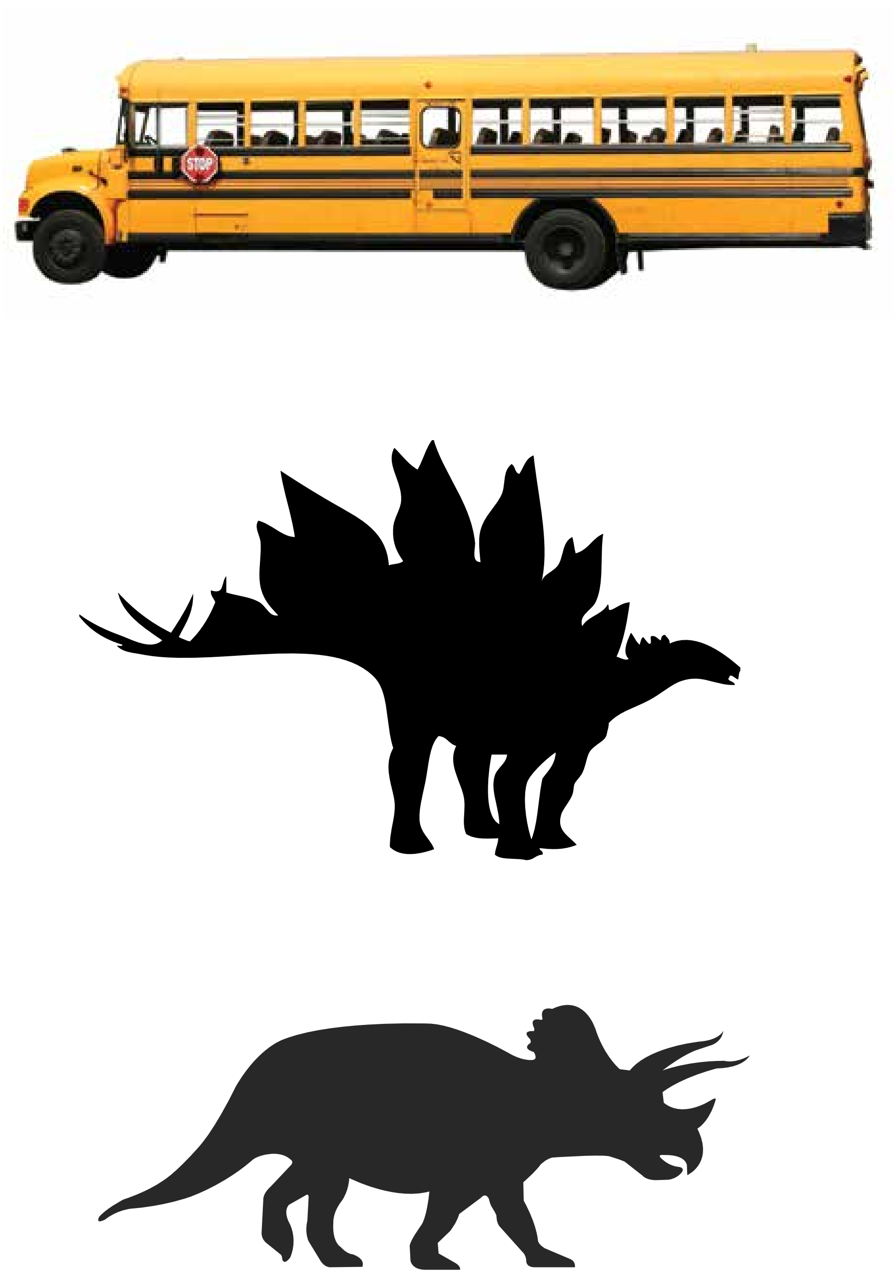
7. The longest school bus is about 14 meters. Match these dinosaurs' lengths to their size, in terms of school buses. (One answer will not be used.)

about ½ a school bus	about 1 ½ school buses
about 1 school bus	about 2 school buses

   a. *Mamenchisaurus* ____________________

   b. *Omeisaurus* ____________________

   c. *Tyrannosaurus rex* ____________________



Stegosaurus *(middle) and* Triceratops *(bottom) were both shorter than a school bus.*

Name Class Date

8. Use the dinosaurs' lengths in feet to make a stem-and-leaf plot to help you answer these questions. Round your answer to the nearest tenth.

Stems	Leaves

a. What is the mean? __________

b. What is the mode? __________

c. What is the median? __________

Time Periods

9. Which two time periods have only one dinosaur on the chart?

10. Count the number of dinosaurs in each of the time periods on the chart.

a. Which time period has the most dinosaurs on the chart?

b. What percentage of the dinosaurs from the list is in that time period? Write your answer as a fraction, reduce the fraction, rewrite it as a decimal, and then calculate the percentage. Remember, there are 10 dinosaurs, so 10 is the denominator for the fraction. To find the percentage, multiply the decimal by 100.

Fraction: __________ Decimal: __________

Reduced fraction: __________ Percent: __________

11. *Triceratops* and *Tyrannosaurus rex* are the two youngest dinosaurs on the chart. They both lived about 65 million years ago.

   a. Write 65 million with all its zeros.

   ____

   b. BONUS! Write 65 million in scientific notation.

   ____

Activity 2: Middle and High School (Grades 6 - 12)

Engineers use scale models to see how something will look or work before they begin building the full-size versions. Architects, car manufacturers, toy makers, roller coaster designers, cartographers (map makers) and many other careers use scale models. All the animatronic dinosaurs you see on your field trip began life as two dimensional drawings on paper. Next, they became scale models, which are the three-dimensional, miniature versions of themselves.

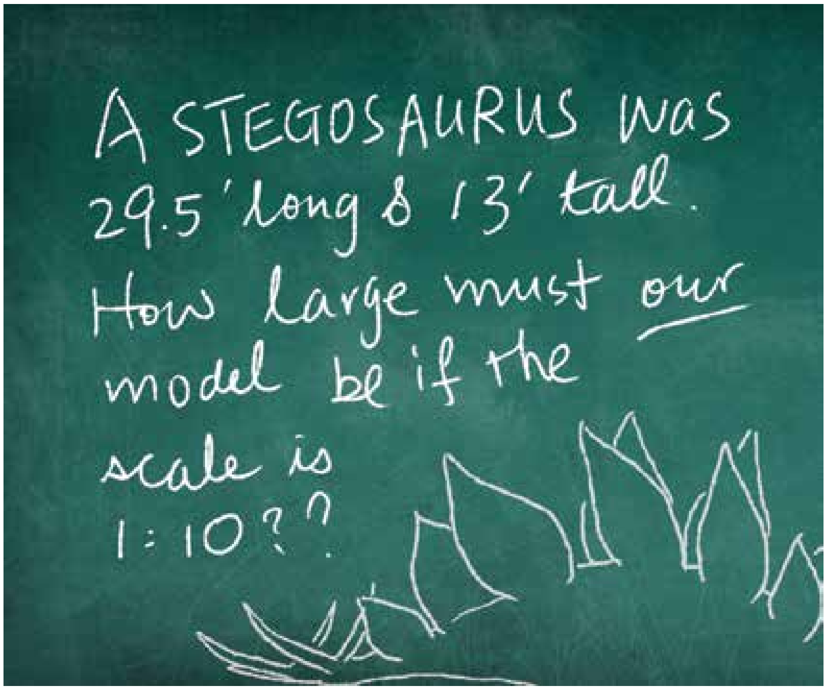
Scale Model

A scale model has the same proportions as the other object, just in a smaller size. For example, if a dinosaur's skull makes up half its entire body, then that needs to be true whether it is a 20-foot model with a 10-foot skull or a 20-inch model with a 10-inch skull. In these activities you will use fractions, ratios, multiplication and measurements to construct and compare scale models to their full-size counterparts.

Scale Factor

Scale factor is the ratio of the corresponding lengths on the scale model to the actual object, written as a fraction. This number tells us how many times bigger the real object is, or how many times smaller the model is. In the example above, of the 20-foot dinosaur with the 10-foot skull, the scale factor for the model is 1/12. The real skull is 12 times bigger than the model skull. The model skull is 1/12th the size of the real skull. (Remember, there are 12 inches in a foot, and we have to reduce the fraction.)

$$\text{scale factor} = \frac{\text{model size}}{\text{object size}} = \frac{10\text{ in}}{10\text{ ft}} = \frac{10\text{ in}}{10\text{ ft X }12\text{ in}} = \frac{10\text{ in}}{120\text{ in}} = \frac{1\text{ in}}{12\text{ in}} = \frac{1}{12}$$



1. A life-size dinosaur statue is 50 times larger than its model. What is the scale factor for the model?

2. If the neck on a real *Mamenchisaurus* was 30 feet long, and the scale factor for its model is 1/10, how long is the neck of the scale model, in feet?

3. You have a model of a *Spinosaurus* that is 2 feet long and you know that it was made with a 1/20 scale factor. How long is the life-size version of *Spinosaurus*? Would it fit in your classroom?

Name ______________________________ Class ______________ Date ______________

4. You have been asked to select, design and engineer the newest life-size animatronic dinosaur for the exhibition. Your first task is to present a scale model.

   a. Choose your favorite dinosaur. Research its length and height.

      My dinosaur: ____

      Length: ______________________ Height: ______________________

   b. Decide what scale factor would allow you to display your dinosaur model on your desk. (Hint: measuring your desk will help.)

      My scale factor: ____

   c. Build the scale model of your dinosaur using arts and crafts supplies like modeling clay, rubber bands, craft sticks, cardboard, cotton balls, Styrofoam, aluminum foil, construction paper, toothpicks, tissue paper, florist wire, feathers, pipe cleaners, straws, hot glue gun, tape, spools, etc.

   d. Display a miniature dinosaur exhibition in your classroom! Build a diorama to re-create the environment in which it lived. Was it a desert or a forest? Prepare a sign with your dinosaur name, pronunciation, brief history and at least one interesting fact. Stand by your display and be available to answer questions and explain how you created your scale model. Create an event and invite students, teachers and your principal.

LESSON 4: FEATHERED DISCOVERIES

During your field trip to *Dinosaurs Unearthed*, you will see dinosaurs now believed to have been born with feathers. Scientists have explored and documented the evolutionary connection between birds and dinosaurs for a long time. However, many questions remain about the specifics of the transition.

How did it happen? When did it happen? Why did it happen? Should we think of birds as living dinosaurs, or the descendants of dinosaurs? New discoveries, especially in China, and new technology available for studying fossil evidence guarantee that the answers to these questions are quickly evolving themselves!

As you will discover during your field trip, feathers are the easiest connection to see between dinosaurs and birds. Paleontologists have found fossilized imprints of feathers that even have traces of the colors they once were.

Penguins and ostriches prove that having feathers doesn't necessarily mean you can fly. Dinosaurs' first feathers probably developed to help keep them warm (like down from a goose). Over time feathers evolved and became specialized. These types of feathers were not only functional flight feathers but also ornamental and were used to attract a mate.

It seems that the fierce *Tyrannosaurus rex* began life as a fuzzy, feathered baby!

Activity 1: Elementary School (Grades K - 5)

One of the reasons birds can fly is the shape of their wings, and the shape of the feathers on those wings. Did you know there are different kinds of feathers with different purposes? Flight feathers need to be light-weight, flexible, and smooth. Let's see how these feathers help a bird, or dinosaur, to fly.

All known fossil specimens of Sinosauropteryx *show signs of feathers and new technology has allowed scientists to figure out the colors of the dinosaur's feathers.*

Name Class Date

Materials

- dictionary
- magnifying glass
- scissors
- 2 pieces of paper
- pencil
- piece of Velcro
- large feather (from craft stores or science supply companies)

Examine your feather. Complete the activities and answer the questions on separate paper.

1. Define these terms:

    a. asymmetrical
    b. barb
    c. barbules
    d. calamus
    e. preen
    f. rachis
    g. vane

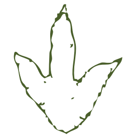
2. Trace your feather on paper. Draw and label these parts on your feather: barb, rachis, vane.

3. The edge of the feather that moves into the wind – the leading edge – has shorter vanes and is convex. The trailing edge has longer vanes and is concave. Label these two sides on your feather diagram.

4. Trace your feather again on another piece of paper. Cut out your paper feather. Try to fold your paper feather in half. Flight feathers need to be asymmetrical to help air flow over the wing. Is your feather symmetrical or asymmetrical?

5. The barbules on the feather keep the barbs together to create a smooth surface for the air to flow over. How do the barbules work? Look closely at your feather with the magnifying glass; now look at the piece of Velcro. Explain how the feather and the Velcro are the same.

Name Class Date



In addition to feathers, dinosaurs and modern birds share over 90 anatomical features including the neck, wrist bones, shoulder blades, oblong eggs, and breastbone.

These feathered dinosaurs, Microraptors*, had four wings – something that definitely did not get passed on to modern birds!*

6. When the barbs on a feather become separated, a bird (and maybe a feathered dinosaur) preens to put them back together. Otherwise, air passes through the feather, instead of over the feather, and makes flying difficult. Look at your feather with the magnifying glass and ruffle the barbs apart by brushing them "backwards." On your paper, draw a close-up of the barbs.

7. Now, "preen" the feather with your thumb and forefinger, to put the barbs back together, while looking through your magnifying glass. On your paper, draw a close-up of the barbs after preening.

8. What did you learn about how flight feathers look? If you found a feather fossil, how would you be able to tell if it was for warmth or flight?

Activity 2: Middle and High School (Grades 6 - 12)

In light of recent discoveries of feathered dinosaurs like *Xiaotingia* in China, the "Court of Dinosaur Science" is now in session in your class. The court is reevaluating the data linking modern birds and ancient dinosaurs before going further into the theories of what happened during the transition and when that transition took place. After viewing some of the feathered dinosaurs during your field trip to *Dinosaurs Unearthed*, you have been asked to review and restate the evidence demonstrating that the similarities between birds and dinosaurs are more than just coincidence or convergent evolutions. You will first gather the evidence, and then present your case.

Name Class Date

Gathering the Evidence

This list describes many of the features dinosaurs share with birds. Read the statement and decide in which category each fact belongs: behavior, skeletal forms and functions, anatomical systems, or feathers. Write the letter for that category in the space provided. The first one has been done for you.

- B = behavior
- S = skeletal forms and functions
- A = anatomical systems
- F = feathers

1.	S	fused collar bone to form a wishbone (furcula)
2.		an anterior positioned pelvis
3.		bipedal with upright stance
4.		nesting sites found with hatchlings and adults together
5.		downy feathers for insulation
6.		elongated arms and forelimbs, arms longer than legs
7.		elongated bones between the ankles and toes (metatarsals)
8.		enlarged sternum (breastbone)
9.		feathers connect directly to the bone (quill knobs)
10.		feathers with vanes, both contour and flight feathers
11.		feet with three main toes pointing forward and one toe pointing back
12.		gastroliths (gizzard stones)
13.		hollow, thin-walled bones, interlaced with blood vessels
14.		long shoulder bone and shoulder positioned for a wide range of movement
15.		medullary bone found in a *T. rex*
16.		oviparous birth and laid eggs with a similar eggshell micro structure
17.		reduced number of fingers, with a long second digit
18.		respiratory system with pulmonary air sacs
19.		scutes
20.		flexible wrists with half-moon shaped wrist bone (semi-lunate carpal)
21.		number of openings in the skull, including large eye sockets
22.		fossils show some dinosaurs slept with their heads tucked under their arms

Name Class Date

23. Which of the categories has the most evidence on the list? Suggest a hypothesis to explain why.

24. Which of the categories has the least evidence on the list? Suggest a hypothesis to explain why.

Presenting your Case

Combine the data you organized above with further research on birds from your science textbook, books from the Recommended Reading list in this Educator's Guide, and the internet. Present your case in the form of a persuasive essay that discusses the similarities between dinosaurs and birds. Be prepared to defend your arguments in a class discussion!

Feathers were found in the fossilized skin impressions of a Dilong, *which is an early tyrannosaurid.* Tyrannosaurus rex *is a well-known tyrannosaurid.*

LESSON 5: FINDING FOSSILS

At present over 700 different species of dinosaurs have been identified and named based on fossil evidence. However, paleontologists believe that there are probably many more dinosaurs that haven't been discovered yet, or that may never be discovered. The only dinosaurs we can know about are the ones that leave the kinds of fossil remains you see at *Dinosaurs Unearthed*, but fossilization is an extremely rare process.

When you think about all the things that have to occur before a fossil ends up in a museum, it's hard to believe it ever happens at all! In this lesson plan, you will practice your paleontological skills and learn about the different ways that dinosaur fossils are formed.

Workers assemble a skeleton model for display.

Activity 1: Elementary School (Grades K - 5)

Even when a fossil does form, there is no guarantee that it will end up close enough to the surface of the Earth to be found by someone who understands what it is and knows what to do with it! Putting a dinosaur skeleton back together is kind of like working a jigsaw puzzle – without knowing how many pieces are in the puzzle or even what the puzzle is supposed to look like when it is finished – which is exactly what you will be doing in this activity!

You are about to find out what it's like to be a real dinosaur detective! First, collect your tools: at least three old jigsaw puzzles in their boxes per team (thrift stores usually have a good selection), plastic bags and team members. Then get to work piecing together these paleontology puzzlers. As you and your team work on the puzzles in each scene, remember that reconstructing dinosaur skeletons is hard work. You may have to try more than one time to complete the task. Keep track of how many attempts it takes to be successful!

More *Allosaurus* fossils have been found than for any other dinosaurs so far.

Name Class Date

Scene 1: A team of paleontologists finds fossilized bones from what might be an *Allosaurus*. It looks like a complete skeleton, but they do not know if any bones are missing.

1. Randomly remove a handful of pieces from a puzzle box and put them in a plastic bag.
2. Keep the remaining pieces in the puzzle box.
3. Trade boxes with another team.
4. See how much of the puzzle can be completed, using the picture on the box as a guide.

Scene 2: A team of paleontologists finds some fossilized bones that they don't recognize. Could it be a new, unidentified species?

1. Randomly remove a handful of pieces from a puzzle box and put them in a plastic bag.
2. Set the remaining pieces and the puzzle box aside.
3. Trade bags with another team.
4. See how much of the puzzle can be completed without the picture on the puzzle's box as a guide.

Scene 3: A team of paleontologists finds another rock formation like the Dashanpu Quarry in China, with fossilized bones scattered around and piled on top of each other. Which bones belong to which dinosaurs?

1. Remove pieces from three different puzzles and put the pieces in a plastic bag.
2. Set the remaining puzzle pieces and boxes aside.
3. Trade bags with another team.
4. See if you can figure out which pieces came from the same puzzle and how much of the puzzle you can put back together.

Scene 4: A team of paleontologists finds a tooth, rib, toe and vertebra buried together. Can the dinosaur be identified with only four fossils? Are they even from the same dinosaur?

1. Randomly select four puzzle pieces.
2. Give them to another team.
3. See if the image on the puzzle (or puzzles) can be correctly identified based only on those four pieces.

Name Class Date

Activity 2: Middle and High School (Grades 6 - 12)

Fossils are formed in several different ways but not all fossilization procedures apply to dinosaurs. For example, while whole insects or plant parts have been found inside hardened amber (tree sap), it's not likely that we will find an entire dinosaur preserved that way. The fossils that we usually think of when talking about dinosaurs are created through permineralization and mineral replacement.

First, the dinosaur has to die. Then – before it rots or is eaten by another dinosaur – its body must be quickly buried under layers of dirt that eventually become sedimentary rock. Mudslides and sand storms are examples of how the carcass could be covered quickly. The soft parts of the dinosaur's body rot away and water seeps into the harder parts of the dinosaur left behind like its teeth, bones, spikes, horns, armored plates or claws.

Minerals in the water slowly fill in the empty spaces in the dinosaur's remains and turn to stone as the water evaporates in permineralization. In mineral replacement, the minerals actually replace the cells of the hard remains and turn them to stone one cell at a time.

Materials:

- Sponge
- Flat pan
- 2 cups of warm water
- 2 tablespoons of salt
- Spoon
- Food coloring
- Sand (enough to cover the sponge)
- Box bigger than the sponge

This is a Hyphalosaurus *fossil from an aquatic reptile that shared the earth with dinosaurs in the Cretaceous Period.*

Recipes for ancient traditional Chinese medicines that called for "dragon bones" were actually using the fossilized bones of dinosaurs.

Name Class Date

Procedure:

1. Place the sponge on the flat pan.
2. Mix the warm water and salt. Stir to dissolve the salt.
3. Add a few drops of food coloring.
4. Pour the salty colored water over the sponge.
5. Saturate the sponge by squeezing out the excess liquid and pouring the liquid over the sponge again a few more times.
6. Put the sponge in the box and pour in enough sand to bury the sponge.
7. Wait for the sponge to dry and harden. This may take a few days.
8. “Excavate” the dry, hard sponge from the sand after all the water has evaporated.

What happened?

1. Hold the sponge up to light. What do you see?

___

2. What do the salt and color represent?

___

3. On separate paper, create a Venn diagram to contrast and compare mineral replacement fossilization with permineralization fossilization.

In plants, this kind of fossilization is called petrification and often happens after lava buries a forest. This fossilized tree trunk is near the Missouri River in Montana.

LESSON 6: TRACES OF DINOSAURS

Fossilized dinosaur bones may tell us what a dinosaur looked like or when and where it lived, but fossils from body parts can't tell us very much about how the dinosaur behaved and moved. Did it walk quickly or slowly? Did it walk on two feet or all fours? Did it drag its tail? Did it live in a herd? Did it build nests for its eggs? Was its skin bumpy? What were its favorite foods?

To answer questions like these about life on Earth millions of years ago, paleontologists study ichnofossils. Mudstone sediments sometimes save impressions of a dinosaur's skin, feathers or footprints. These ichnofossils, or fossils of imprint, along with fossilized eggshells and nests are also called trace fossils.

The first decade of the 21st century has seen rogue fossil hunters steal everything from a set of 30 theropod footprints in England to hundreds of eggs from China and Mongolia.

Activity 1: Elementary School (Grades K - 5)

One dinosaur could make a lot of footprints in its lifetime, which is why there are more places in the world with trackways than with fossilized dinosaur body parts. But not every footprint can be preserved. A footprint surviving as a trace fossil depended on the kind of dirt where the dinosaur was walking. Scientists have figured out that the places where they find trackways were once marshy or muddy.

Think about the last time you walked in the snow, sand or mud. How long did your footprints show before they faded away? In this activity you will see why the kinds of places the dinosaurs walked determined whether or not their footprints would be found millions of years later.

Materials

- Shallow pie pan
- Water
- Soil, at least 2 cups
- Medical/latex gloves
- Tablespoon
- Newspaper or drop cloth
- Stopwatch

This ichnofossil is a footprint from a dinosaur with three toes ("tridactyl"), which means it was probably left by a theropod whose fourth toe faced backwards and usually didn't touch the ground.

Name Class Date

Procedure

1. Cover your work space with newspapers or a drop cloth.
2. Put the soil in the pan but do not fill the pan all the way to the top.
3. Put a glove on one hand and press that hand into the pan for 10 seconds
4. Examine the print left behind as soon as you take your hand out. What does the print look like after 1 minute has passed? Record your notes in the chart below.

	Immediately	After 1 Minute
Imprint		

5. Add water to the pan, one tablespoon at a time. Stir in the water and repeat Steps #3 and 4.
6. Keep track of how much water made the soil muddy enough to hold the imprint.

What happened?

1. What happened to your hand imprint when the soil was too dry?

2. What happened to your hand imprint when the soil was too wet?

3. Describe the consistency of the soil when it made the best imprint.

4. Does the weight of a dinosaur affect its footprints? Why or why not? What do you think would happen if you pressed your hand harder or lighter into the pan?

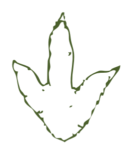
Name Class Date

Try it!

- Keep your pinkie and ring fingers pressed together and your middle and pointer fingers together. Your hand print will be the shape of a three-toed theropod!

- Repeat the experiment with sand and gravel. Compare those outcomes to the soil to see which one makes the best prints. Based on your results, where are paleontologists more likely to find trackways?

- Send a sample of the soil you used to your local extension agency to have it analyzed. Do the components of the soil make it a likely place for trace fossils to be found millions of years in the future? Are there any known trackways in your area now?



In the 1800s, dinosaur coprolite was mined in England for use as fertilizer. During World War I, it was used in the making of munitions!

Activity 2: Middle and High School (Grades 6 - 12)

At the exhibition you will read that dinosaur droppings are also trace fossils. On the next page, read each question about dinosaurs. Decide if it is a question that paleontologists can answer by looking at trackways (paths of foot prints), if it is something that can be learned by studying coprolite (fossilized dinosaur dung), or if it is something that can't be figured out by looking at either kind of trace fossil. Then write the letter in the appropriate space provided. The first one has been done for you.

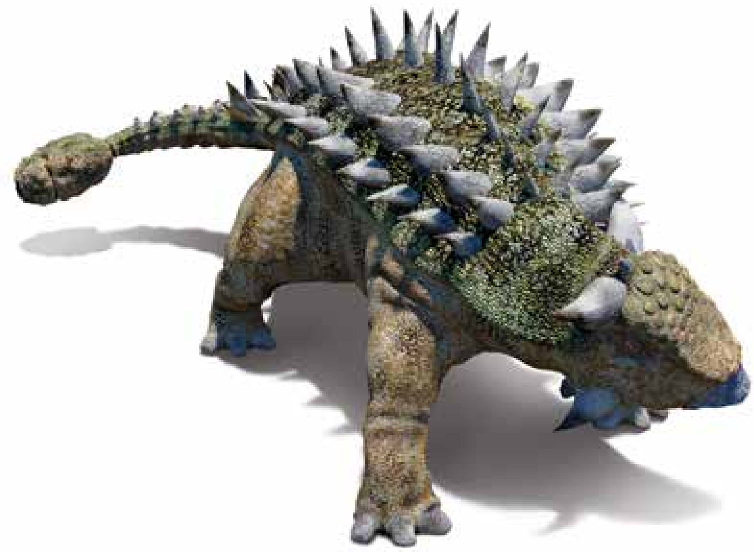
- T = trackway
- C = coprolite
- N = neither

1.	T	Was the dinosaur a quadruped or biped?
2.		Which dinosaur left the trace fossil?
3.		What grasses and trees were on Earth at that time?
4.		Was the dinosaur a carnivore?
5.		Was the dinosaur chased by a predator?
6.		Did the dinosaur drag its tail or carry it off the ground?
7.		Did the dinosaur live in a herd?
8.		Did the dinosaur chew its food or swallow it whole?
9.		Was the dinosaur running or walking at that moment in time?
10.		If the trace fossil was left by a carnivore, what smaller animals lived at the same time?

CROSSWORD PUZZLES

Name that Dinosaur!

Dinosaurs' names are often made of words from other languages. The name can describe the dinosaur's body, the place where it was found, or even the person who found it. For example, *Acrocanthosaurus* is Greek for "high-spined lizard" which is an accurate description of what it looked like. *Gobisaurus* was named for the Gobi Desert where the fossil was found. *Lambeosaurus* was named for paleontologist Lawrence Lambe. Read the clues for these puzzles and find the dinosaur whose name has that meaning. A word bank is provided for the first puzzle.



This is Dyoplosaurus, *whose name means "double-armored lizard."*

***Gasosaurus* was named for the gas company under construction when the dinosaur was discovered!**

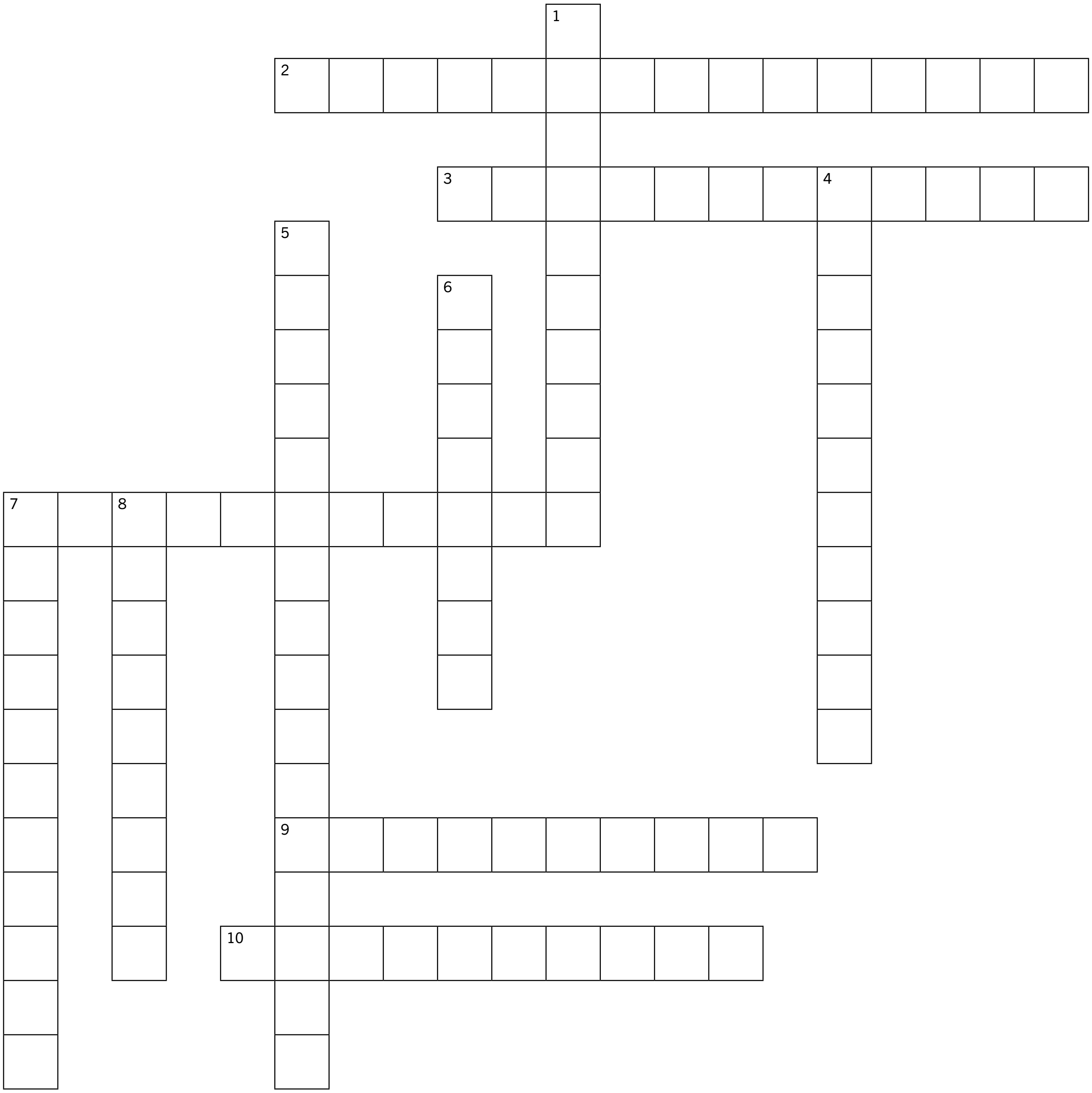
The longest dinosaur name is *Micropachycephalosaurus*, which means "tiny, thick-headed lizard."

Level 1:

Across		Down	
2.	Strange-ankled lizard	1.	Chicken mimic
3.	Fast thief	4.	Agile lizard
7.	Three-horned face	5.	Thick-nosed lizard
9.	Different lizard	6.	Heavy claw
10.	Slow leg	7.	Swollen head
		8.	Iguana tooth

Agilisaurus	*Gallimimus*	*Tylocephale*
Allosaurus	*Iguanodon*	*Velociraptor*
Baryonyx	*Pachyrhinosaurus*	*Xenotarsosaurus*
Bradycneme	*Triceratops*	

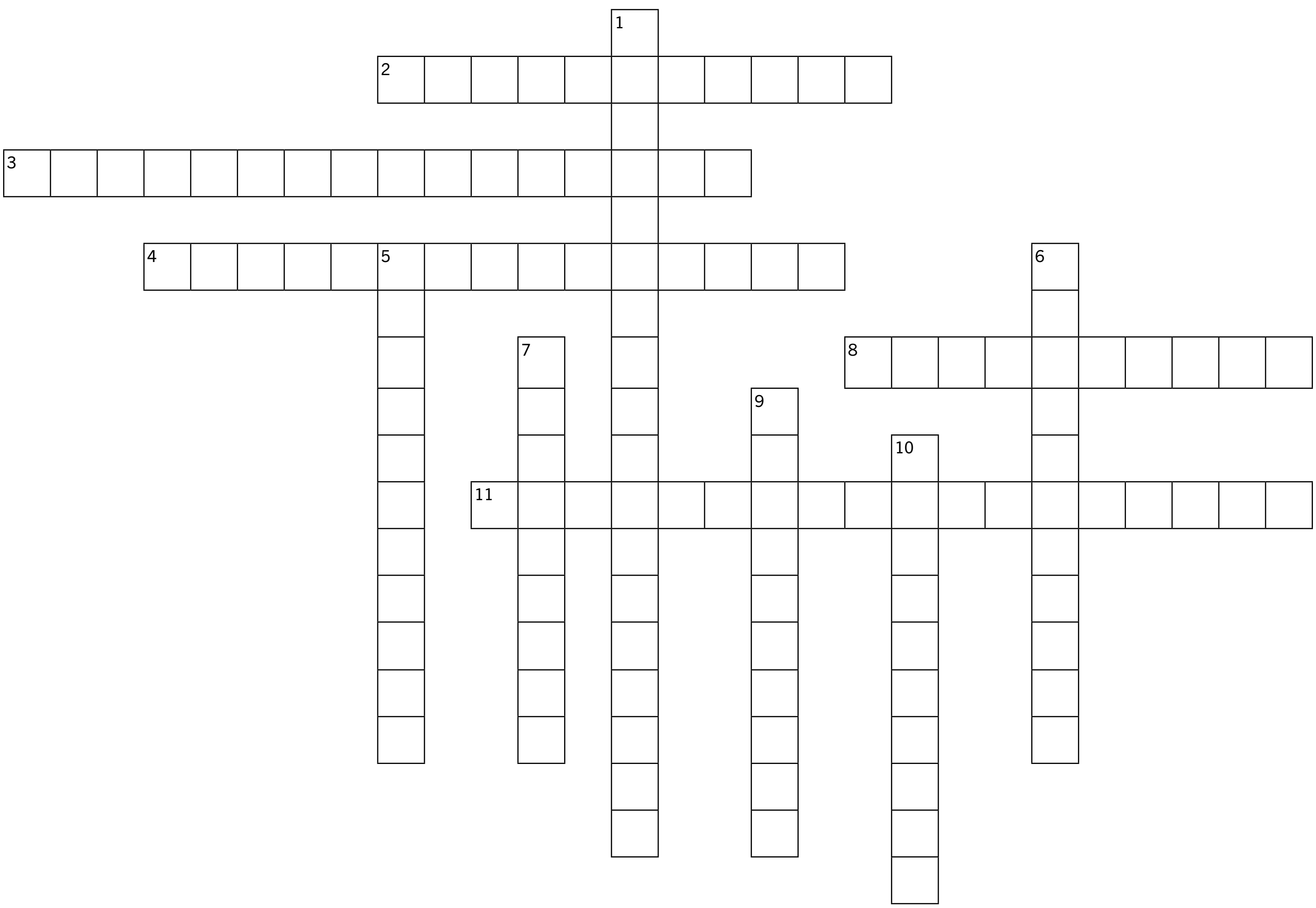
Name Class Date



Name Class Date

Level 2

Across		Down	
2.	Swollen head	1.	Medium-spined lizard
3.	Lizard from Yang-Ch'uan	5.	Deceptive lizard
4.	Lizard with strange ankles	6.	Agile lizard
8.	Chicken mimic	7.	Iguana tooth
11.	Lizard with a thick head	9.	Lizard from Mount Emei
		10.	Dwarf lizard



LOGIC PUZZLES

Logic puzzles are a fun way to practice critical thinking skills and key math concepts, while also learning more about some of the dinosaurs you may encounter during your field trip. The trick to solving a logic puzzle is to narrow down your options and use your deductive reasoning skills.

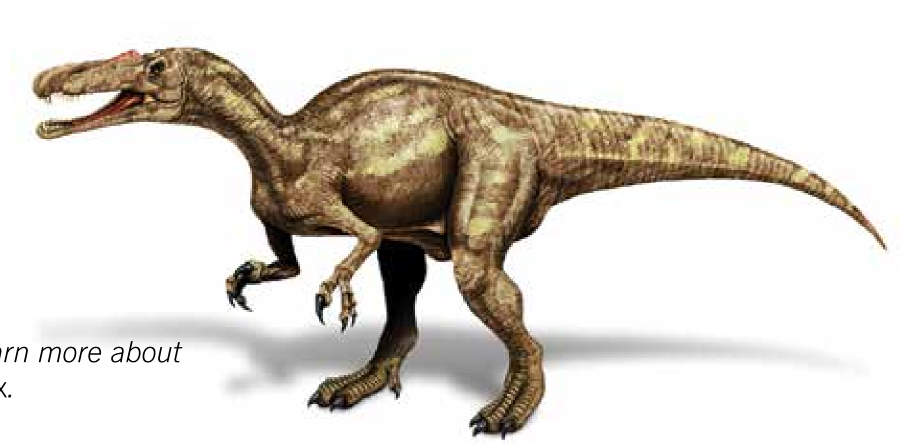
Start eliminating options by following the clues in the logic puzzle that clearly state if something is not true and placing an X in the appropriate box. Slowly but surely, you will begin narrowing down the possibilities. When you finish all the clues and still haven't completed the logic puzzle, read through the clues one at a time again. Once you make some basic deductions, you will be able to learn new things and come closer to solving the puzzle. Select Level 1 or Level 2 (or both!) and start thinking logically! Some clues have been marked to help you get started.

Sorting Fossils

You are the newest intern at the local natural history and science museum. Your first task is to organize a storage room with fossils from different dinosaurs. Unfortunately, the paleontologists who recovered the fossils did not take very good field notes. The only facts you have about these fossils are listed below. Use the logic puzzle charts to help you identify and describe each dinosaur.

The remains of a "new" species of Ceratopsia dinosaur, called *Mojoceratops,* were recently "discovered" mixed in a with a similar set of fossils at the American Museum of Natural History in New York City.

In 2011 scientists examined a fossil of a *Protoceratops* which had been unearthed in 1965. They were surprised to discover that the surrounding matrix contained the dinosaur's footprint.



Solve the logic puzzles to learn more about the fossils from this Baryonyx.

Name Class Date

LEVEL 1

Clues:

1. *Parasaurolophus* did not come from China.
2. *Mamenchisaurus* is not from the Late Cretaceous Period.
3. The dinosaur from the Late Jurassic Period was from China.
4. The *Baryonyx* fossil was found in Europe.
5. The dinosaur that came from North America is not from the Early Cretaceous Period.

Chart:

	Late Jurassic	Late Cretaceous	Early Cretaceous	Europe	China	North America
Parasaurolophus					X	
Baryonyx						
Mamenchisaurus						
Europe						
China						
North America						

Name Class Date

LEVEL 2

Read this list of hints and tips to help you solve this advanced logic puzzle. Remember to narrow down your options using your critical thinking skills. Two clues have been marked on the puzzle to get you started. Good luck sorting through these fossils!

1. Read through the entire list of clues at least once before making any marks on your chart.

2. Eliminate options by following the clues, one by one, and looking for definitive statements. If a connection is stated explicitly in the clues, then mark it on the chart. For example, the first clue states that the dinosaur that is 4 feet long lived before *Apatosaurus*. Therefore, *Apatosaurus* cannot be the dinosaur that IS 4 feet long. Place an X in the box where the column for "*Apatosaurus*" intersects the row for "4 feet."

3. Mark all the obvious questions stated in the rest of the clues, the same way you did in the step above. For example, based on the information in clue #4, we can place an X in the box where the column for "30 feet" intersects the row for "Mongolia." We can also place Xs in the boxes where the columns for both "*Baryonyx*" and "*Agilisaurus*" intersect the row for "Mongolia."

4. Slowly but surely you will begin narrowing down your fields. Some answers will become apparent as other options are eliminated. For example, after marking the obvious information from the clues the first time through, you will have all the pieces of information you need to identify "*Apatosaurus.*"

5. After all the clear connections have been made, re-read the list of clues, keeping in mind what you know now. For example, since we now know the name, length, location and time period for "*Apatosaurus*," they become equivalent terms and are interchangeable within the wording of the clues. Any time one of them appears in a clue, you can replace it with one of the other aspects for the *Apatosaurus*.

6. Read back through the clues and use the substitution method from hint #5 every time you correctly connect two or more pieces of information. Replacing a term with one of its "equivalents" will reveal more information. For example, based on clue #9, you can substitute "Late Jurassic" in any clue where "70-foot dinosaur" is mentioned. Using that information in clue #5 tells us that the fossils from the Late Jurassic Period were found either in the US and Mexico or in Mongolia. Now you also know you can place an X in the boxes where the column for "Late Jurassic" intersects the columns of the other two locations, China and Europe.

7. You will need to read through your clues many times. Be diligent! If you get stuck, check your chart to see if any connections have revealed themselves "accidentally" as you worked through the process of elimination. Look for tricky language in the clues too like "either/or" and "neither/nor."

Name Class Date

Clues:

1. The 4-foot dinosaur lived before *Apatosaurus*.
2. The 70-foot dinosaur lived before *Protoceratops*.
3. Of *Apatosaurus* and *Baryonyx*, one lived in the Late Jurassic Period and the other was 30 feet long.
4. The fossils found in Mongolia are not from a 30-foot dinosaur and are neither a *Baryonyx* nor *Agilisaurus*.
5. The 70-foot dinosaur is either from the US and Mexico or Mongolia.
6. *Apatosaurus* is neither 5 - 8 feet nor 30 feet long.
7. The dinosaur from the Early Cretaceous Period was found in Europe.
8. The fossils found in the US and Mexico do not belong to *Protoceratops*.
9. The dinosaur from the Late Jurassic Period is 70 feet long.
10. The fossils found in Mongolia are not from a 70-foot dinosaur.

Chart:

	Apatosaurus	*Baryonyx*	*Protoceratops*	*Agilisaurus*	70 ft	30 ft	4 ft	5 – 8 ft	US and Mexico	Mongolia	China	Europe
Mid-Jurassic												
Late Jurassic												
Early Cretaceous												
Late Cretaceous												
US and Mexico												
Mongolia						X						
China												
Europe												
70 ft.												
30 ft.												
4 ft.	X											
5 - 8 ft.												

Name Class Date

WORD SEARCH

Dinosaur Vocabulary

Search vertically, horizontally and diagonally for dinosaur and paleontology terms in the puzzles. BONUS! Define each word in the puzzle. Hint: There is a glossary at the end of this Educator's Guide.

Lower Level:

ALXASAURUS	FEATHERS	MESOZOIC	TRACKWAY
CRETACEOUS	*GIGANTORAPTOR*	PALEONTOLOGIST	TRIASSIC
DINOSAUR	JURASSIC	PANGAEA	*VELOCIRAPTOR*

T	N	F	U	C	A	D	Z	X	C	H	R	K	R
S	S	G	C	R	E	T	A	C	E	O	U	S	O
A	Q	I	P	W	H	B	M	V	T	Y	W	G	T
P	L	H	G	Q	C	E	W	P	I	A	T	O	P
P	M	X	K	O	S	I	A	V	N	W	D	D	A
R	A	B	A	O	L	R	S	Q	M	K	N	B	R
A	N	N	Z	S	I	O	D	S	J	C	H	O	O
S	U	O	G	C	A	K	T	A	A	A	X	O	T
L	I	D	O	A	G	U	R	N	Z	R	I	O	N
C	Q	L	Y	E	E	Z	R	P	O	T	U	M	A
Q	E	V	O	C	I	A	H	U	Y	E	G	J	G
V	C	I	S	S	A	I	R	T	S	G	L	J	I
E	A	Q	N	F	E	A	T	H	E	R	S	A	G
A	D	I	N	O	S	A	U	R	P	D	H	D	P

Name Class Date

Level 2:

ALXASAURUS	JURASSIC	SAUROPOD
COPROLITE	MESOZOIC	*STEGOSAURUS*
CRETACEOUS	*MICRORAPTOR*	THEROPOD
DILOPHOSAURUS	ORNITHOPOD	TRACKWAY
FOSSILS	OVIPAROUS	TRIASSIC
GIGANTORAPTOR	*PARASAUROLOPHUS*	*TYRANNOSAURUS*

K	R	Q	F	B	D	X	K	C	L	R	R	D	G	M	O	C	T	T	T	Y	G
N	Z	O	G	O	E	P	D	I	L	O	P	H	O	S	A	U	R	U	S	C	S
O	O	I	T	S	S	H	S	U	H	P	O	L	O	R	U	A	S	A	R	A	P
R	B	S	O	P	E	S	A	F	Y	Y	F	T	A	L	C	F	J	H	B	I	S
E	E	U	A	R	A	D	I	O	O	G	N	P	G	K	R	Z	Z	F	E	H	U
I	R	E	A	U	F	R	C	L	O	I	T	R	W	P	J	P	T	D	H	J	R
U	O	V	I	P	A	R	O	U	S	O	U	A	V	L	R	N	G	B	O	D	U
H	B	W	A	D	I	U	P	R	R	S	Y	R	L	A	M	I	N	M	O	R	A
X	O	U	N	X	R	P	S	P	C	J	U	R	A	S	S	I	C	P	O	G	S
E	T	A	O	O	C	S	Q	I	D	I	O	G	F	R	U	T	O	T	C	T	O
C	I	S	S	A	I	R	T	S	O	V	M	N	Z	T	M	R	P	D	A	J	G
R	V	D	I	M	O	V	Y	Z	P	F	M	O	M	A	E	A	R	I	T	Z	E
E	C	M	A	Z	Z	Q	R	F	O	G	D	V	W	H	R	G	O	D	D	F	T
T	Z	Q	S	P	O	I	A	E	R	N	J	I	T	O	E	S	L	O	Y	N	S
A	C	E	X	S	S	Q	N	M	U	P	R	W	T	Q	V	U	I	P	E	K	B
C	B	T	P	L	E	I	N	Y	A	E	O	N	M	C	F	D	T	O	F	V	U
E	T	O	I	A	M	Q	O	A	S	K	A	Z	S	W	N	C	E	H	N	S	D
O	T	Q	E	X	A	S	S	G	Q	G	Z	H	J	E	G	B	T	T	H	B	Z
U	B	K	Q	N	Q	B	A	G	I	B	A	J	G	M	V	D	Q	I	O	T	M
S	N	D	M	C	F	N	U	G	T	R	T	Y	L	R	R	L	W	N	E	T	G
O	A	S	A	V	Y	K	R	V	H	M	V	R	J	W	B	D	T	R	F	J	C
X	E	I	T	O	G	A	U	Y	F	Q	R	W	M	G	X	Y	N	O	Y	D	A
H	A	L	A	L	X	A	S	A	U	R	U	S	A	E	I	Q	L	B	N	V	S

ANSWER KEYS

Field Trip Activity

1. *Triceratops* juvenile
2. *Allosaurus* juvenile
3. *Stegosaurus* juvenile
4. *Protoceratops*
5. *Ruyangosaurus*
6. *Yangchuanosaurus juvenile*
7. *Velociraptor*
8. *Microraptor*
9. *Tyrannosaurs rex juvenile*
10. *Protoceratops*
11. Late Cretaceous
12. Colorado, Montana, Wyoming
13. Alberta
14. (in chronological order)

Yangchuanosaurus	Late Jurassic	160 Mya
Allosaurus	Late Jurassic	150 Mya
Stegosaurus	Late Jurassic	150 Mya
Microraptor	Early Cretaceous	125 Mya
Ruyangosaurus	Late Cretaceous	99.6 - 89.3 Mya
Protoceratops	Late Cretaceous	75 Mya
Velociraptor	Late Cretaceous	75 Mya
Triceratops	Late Cretaceous	65 Mya
Tyrannosaurus rex	Late Cretaceous	65 Mya

Lesson 1: Form and Function

Activity 1: Elementary School (Grades K - 5)

1. Answers will vary 2. No

Activity 2: Middle and High School (Grades 6 - 12)

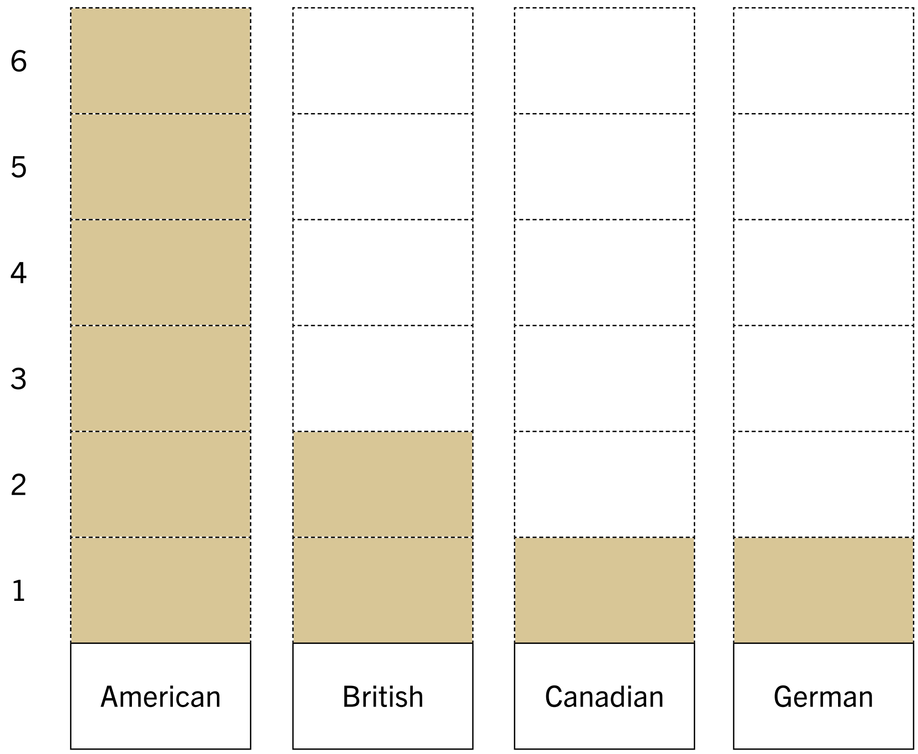
1. k 2. e 3. g 4. j 5. c 6. b 7. d 8. l 9. f 10. a 11. h 12. i 13. a large sauropod: *Apatosaurus*

Lesson 2: Dinosaur Detectives

Activity 1: Elementary School (Grades K - 5)

Name	Birth-Death	Nationality	Answers may vary: dinosaur named may include...
Roy C. Andrews	1884-1960	American	*Oviraptor, Velociraptor, Saurornithoides*
Barnum Brown	1873-1963	American	*Ankylosaurus, Corythosaurus, Leptoceratops, Saurolophus*
William Buckland	1784-1856	British	*Megalosaurus*
Edward D. Cope	1840-1897	American	*Camarasaurus, Coelophysis, Dimetrodon*
Lawrence M. Lambe	1849-1934	Canadian	*Chasmosaurus, Edmontosaurus, Euoplocephalus, Styracosaurus*
Joseph Leidy	1823-1891	American	*Hadrosaurus*
Gideon Mantell	1790-1852	British	*Iguanodon, Hylaeosaurus*
Othniel C. Marsh	1831-1899	American	*Allosaurus, Apatosaurus, Diplodocus, Stegosaurus, Triceratops*
Henry F. Osborn	1857-1935	American	*T. rex, Pentaceratops, Ornitholestes, Velociraptor*
Hermann von Meyer	1801-1869	German	*Archaeopteryx, Rhamphorhynchus, Plateosaurus*

1. William Buckland, 1784.
2. American.
3. Answers may vary. Best answers should suggest that more dinosaurs were found in America at that time than anywhere else.
4. Bar graph:



Activity 3: Middle and High School (Grades 6 - 12)

1. Physicist: described how an asteroid striking the Earth led to the dinosaurs' extinction.
2. Sculptor/artist: created the first dinosaur models and statues.
3. Geologist: proposed a geologic time scale, estimated the age of the Earth as old enough to include millions of years of dinosaurs.
4. Meteorologist/geologist: proposed the theory of continental drift (plate tectonics), which explains how the same dinosaurs are found on different continents.

Lesson 3: Mesozoic Math

Activity 1 : Elementary School (Grades K - 5)

1. *Baryonyx*
2. *Baryonyx, Parasaurolophus, Stegosaurus, Triceratops*
3. *Tyrannosaurus rex*

4. a) 132 m b) 435.6 ft
5. 24 ÷ 4 = 6
6. (activity)
7. a) about 2 b) about 1½ c) about 1
8. a) 43.6 ft b) 29.7 ft c) 34.7 ft
9. Early Cretaceous, Mid-Jurassic
10. a) Late Jurassic b) 5/10 = ½ = 0.5 = 50%
11. a) 65,000,000 b) $6.5 X 10^7$

Activity 2: Middle and High School (Grades 6 - 12)

1. 1/50
2. 3 feet
3. 40 feet, probably not

Lesson 4: Feathered Discoveries

Activity 1 : Elementary School (Grades K - 5)

1. Definitions:
    a. asymmetrical: not symmetrical, different on both sides
    b. barb: the part of the feather branching off the rachis, running parallel to each other
    c. barbules: tiny, hair-like branches that come off the barb and have tiny hooks
    d. calamus: quill, the end part of the rachis, that goes into the bird
    e. preen: the way a bird cleans it feathers by pulling the barbs through its beak
    f. rachis: the central branch or shaft that runs down the length of the feather, like the trunk of a tree
    g. vane: the flat part of the feather, with the barbs that hook together on both sides of the rachis
10. asymmetrical
11. One side of the Velcro has tiny hooks that catch onto the other side, like some of the barbules hook onto other barbules next to them to hold the barbs together.

Activity 2 : Middle and High School (Grades 6 - 12)

1. S 2. S 3. S 4. B 5. F 6. S 7. S 8. S 9. F 10. F 11. S 12. A 13. S 14. S 15. A 16. A 17. S 18. A 19. F 20. S 21. S 22.B

23. Skeletal, because most fossils come from bones/skeletons.
24. Behavior, because behavior has to be inferred from fossils and other findings and does not leave physical evidence on its own.

Lesson 5: Finding Fossils

Activity 2 : Middle and High School (Grades 6 - 12)

1. The sponge should be the color of the food coloring. You should see crystals from the salt.
2. They are like the minerals that are left behind in the dinosaur's remains when the water evaporates.
3. Answers may vary.

Lesson 6: Traces of Dinosaurs

Activity 1 : Elementary School (Grades K - 5)

1. It was hard to see the imprint.
2. The imprint washed away or filled in with water.
3. Answers will vary.
4. Yes, when you press harder into the pan, it would make a deeper impression and heavier dinosaurs would have left deeper footprints.

Activity 2 : Middle and High School (Grades 6 - 12)

1. T 2. N 3. C 4. C 5. T 6. T 7. T 8. C 9. T 10. C

Crossword Puzzles

Lower level

Across: 2. *Xenotarsosaurus* 3. *Velociraptor* 7. *Triceratops* 9. *Allosaurus* 10. *Bradycneme*
Down: 1. *Gallimimus* 4. *Agilisaurus* 5. *Pachyrhinosaurus* 6. *Baryonyx* 7. *Tylocephale* 8. *Iguanodon*

Upper Level

Across: 2. *Tylocephale* 3. *Yangchuanosaurus* 4. *Xenotarsosaurus* 8. *Gallimimus* 11. *Pachycephalosaurus*
Down: 1. *Metriacanthosaurus* 5. *Apatosaurus* 6. *Agilisaurus* 7. *Iguanadon* 9. *Omeisaurus* 10. *Nanosaurus*

Logic Puzzles

Lower level

Parasaurolophus – Late Cretaceous – North America
Baryonyx – Early Cretaceous – Europe
Mamenchisaurus – Late Jurassic – China

Upper level

Mid-Jurassic – *Agilisaurus* – 4 feet – China
Late Jurassic – *Apatosaurus* – 70 feet – US and Mexico
Early Cretaceous – *Baryonyx* – 30 feet – Europe
Late Cretaceous – *Protoceratops* – 5 – 8 feet – Mongolia

Word Searches

Lower Level

T	N	F	U	C	A	D	Z	X	C	H	R	K	R
S	S	G	C	R	E	T	A	C	E	O	U	S	O
A	Q	I	P	W	H	B	M	V	T	Y	W	G	T
P	L	H	G	Q	C	E	W	P	I	A	T	O	P
P	M	X	K	O	S	I	A	V	N	W	D	D	A
R	A	B	A	O	L	R	S	Q	M	K	N	B	R
A	N	N	Z	S	I	O	D	S	J	C	H	O	O
S	U	O	G	C	A	K	T	A	A	A	X	O	T
L	I	D	O	A	G	U	R	N	Z	R	I	O	N
C	Q	L	Y	E	E	Z	R	P	O	T	U	M	A
Q	E	V	O	C	I	A	H	U	Y	E	G	J	G
V	C	I	S	S	A	I	R	T	S	G	L	J	I
E	A	Q	N	F	E	A	T	H	E	R	S	A	G
A	D	I	N	O	S	A	U	R	P	D	H	D	P

Upper Level

K	R	Q	F	B	D	X	K	C	L	R	R	D	G	M	O	C	T	T	T	Y	G
N	Z	O	G	O	E	P	D	I	L	O	P	H	O	S	A	U	R	U	S	C	S
O	O	I	T	S	S	H	S	U	H	P	O	L	O	R	U	A	S	A	R	A	P
R	B	S	O	P	E	S	A	F	Y	Y	F	T	A	L	C	F	J	H	B	I	S
E	E	U	A	R	A	D	I	O	O	G	N	P	G	K	R	Z	Z	F	E	H	U
I	R	E	A	U	F	R	C	L	O	I	T	R	W	P	J	P	T	D	H	J	R
U	O	V	I	P	A	R	O	U	S	O	U	A	V	L	R	N	G	B	O	D	U
H	B	W	A	D	I	U	P	R	R	S	Y	R	L	A	M	I	N	M	O	R	A
X	O	U	N	X	R	P	S	P	C	J	U	R	A	S	S	I	C	P	O	G	S
E	T	A	O	O	C	S	Q	I	D	I	O	G	F	R	U	T	O	T	C	T	O
C	I	S	S	A	I	R	T	S	O	V	M	N	Z	T	M	R	P	D	A	J	G
R	V	D	I	M	O	V	Y	Z	P	F	M	O	M	A	E	A	R	I	T	Z	E
E	C	M	A	Z	Z	Q	R	F	O	G	D	V	W	H	R	G	O	D	D	F	T
T	Z	Q	S	P	O	I	A	E	R	N	J	I	T	O	E	S	L	O	Y	N	S
A	C	E	X	S	S	Q	N	M	U	P	R	W	T	Q	V	U	I	P	E	K	B
C	B	T	P	L	E	I	N	Y	A	E	O	N	M	C	F	D	T	O	F	V	U
E	T	O	I	A	M	Q	O	A	S	K	A	Z	S	W	N	C	E	H	N	S	D
O	T	Q	E	X	A	S	S	G	Q	G	Z	H	J	E	G	B	T	T	H	B	Z
U	B	K	Q	N	Q	B	A	G	I	B	A	J	G	M	V	D	Q	I	O	T	M
S	N	D	M	C	F	N	U	G	T	R	T	Y	L	R	R	L	W	N	E	T	G
O	A	S	A	V	Y	K	R	V	H	M	V	R	J	W	B	D	T	R	F	J	C
X	E	I	T	O	G	A	U	Y	F	Q	R	W	M	G	X	Y	N	O	Y	D	A
H	A	L	A	L	X	A	S	A	U	R	U	S	A	E	I	Q	L	B	N	V	S

RECOMMENDED READING

Consult these books to learn more about your favorite dinosaurs. Build your own dinosaur library to follow up on what you learned during your field trip and explore the latest discoveries and theories in dinosaur research.

Ages 4 - 8

Hughes, Catherine D. *National Geographic Little Kids First Big Book of Dinosaurs*. National Geographic Children's Books, 2011.

Judge, Lita. *Born to be Giants: How Baby Dinosaurs Grew to Rule the World*. Flash Point, 2010.

Kudlinski, Kathleen V. *Boy, Were We Wrong About Dinosaurs!* Puffin, 2008.

Priddy, Roger. *My Big Dinosaur World*. Priddy Books, 2008.

Theodorou, Rod. *I Wonder Why Triceratops Had Horns*. Kingfisher, 2011.

Zoehfeld, Kathleen Wiedner. *Where Did Dinosaurs Come From?* Collins, 2010.

Zoehfeld, Kathleen Wiedner. *Did Dinosaurs Have Feathers?* Collins, 2003.

Zoehfeld, Kathleen Wiedner. *National Geographic Readers: Dinosaurs*. National Geographic Children's Books, 2011.

Ages 9 - 12

Barrett, Paul. *National Geographic Dinosaurs*. National Geographic Children's Books, 2001.

Bishop, Nic. *Digging for Bird Dinosaurs: An Expedition to Madagascar (Scientists in the Field Series)*. Sandpiper, 2002.

Editors of TIME for Kids Magazine, TIME For Kids Dinosaurs 3D: An Incredible Journey Through Time, Time for Kids Books, 2013

Holmes, Thom. *Feathered Dinosaurs: The Origins of Birds*. Enslow, 2002.

Lambert, David. *Dinosaur (DK Eyewitness Books)*. DK Children, 2010.

Manning Phillip. *Dinomummy*. Kingfisher, 2007.

Parker, Steve. *Age of Dinosaurs*. Natural History Museum, 2011.

Williams, Judith. *The Discovery and Mystery of a Dinosaur Named Jane*. Enslow, 2007.

Young Adult and Above

Brusatte, Steve & Michael Benton. *Dinosaurs*. Quercus, 2010.

Chen, Pei-ji, Yuan-ging Wang, & Mee-Mann Chang (eds). *The Jehol Fossils: The Emergence of Feathered Dinosaurs, Beaked Birds & Flowering Plants*. Academic Press, 2008.

Currie, Philip J. & Josh Long. *Dino Gangs*. Collins, 2011.

Holtz, Thomas R. *Dinosaurs: The Most Complete, Up-to-Date Encyclopedia for Dinosaur Lovers of All Ages*. Random House Books for Young Readers, 2007.

Hone, David. *The Tyrannosaur Chronicles*, Bloomsbury Sigma, 2016

Long, John. *Feathered Dinosaurs: The Origin of Birds*. Oxford University Press USA, 2008.

Naish, Darren. *The Great Dinosaur Discoveries*. University of California Press, 2009.

Sampson, Scott D. *Dinosaur Odyssey: Fossil Threads in the Web of Life*. University of California Press, 2011.

With the increase in new discoveries and theories about feathered dinosaurs, like Confuciusornis, *the transition between dinosaurs and birds is often discussed in recent dinosaur literature.*

ONLINE RESOURCES

The following online resources are just some of our favourites for staying current when it comes to the ever changing new discoveries concerning dinosaur research. As with all online resources, some links may move as authors change formats and other sites may come to the forefront. The following links, for the most part written by paleontologists and students of paleontology, are exceptional classroom resources.

Archosaur Musings
http://archosaurmusings.wordpress.com/

Sauropod Vertebrae Picture of the Week
http://svpow.com/

Laelaps
http://blogs.scientificamerican.com/laelaps/

Mark Witton
http://markwitton-com.blogspot.ca/

Chinleana
http://chinleana.fieldofscience.com/

Pseudoplocephalus
https://pseudoplocephalus.com/

Palaeoblog
https://www.facebook.com/Palaeoblog

Lost Worlds Revisited
https://www.theguardian.com/science/series/lost-worlds-revisited

Love in the Time of Chasmosaurs
http://chasmosaurs.blogspot.ca/

Dinosaur CSI
http://dinosaursabbatical.blogspot.ca/

Pterosaur.net
http://pterosaur.net/

The following blogs have been archived and although no new material is being added in the links below the information still valuable to anyone interested in dinosaurs and paleontology.

http://blogs.smithsonianmag.com/dinosaur/
http://palaeoblog.blogspot.ca/
http://phenomena.nationalgeographic.com/blog/laelaps/

DINOSAUR DATA

Do you want a crash course in paleontology? Here is what you need to know about some of the dinosaurs you will encounter on your field trip. Impress your friends and family as you rattle off these fascinating facts.

For each dinosaur, you will find the order, suborder, meaning of the name, how to pronounce the name, the period in which it lived, the locations where fossils have been found, the estimated length and height and the year in which that dinosaur was officially named. Each dinosaur also has three Quick Facts that you definitely want to check out along with additional background information to introduce you to your new favorite prehistoric creatures.

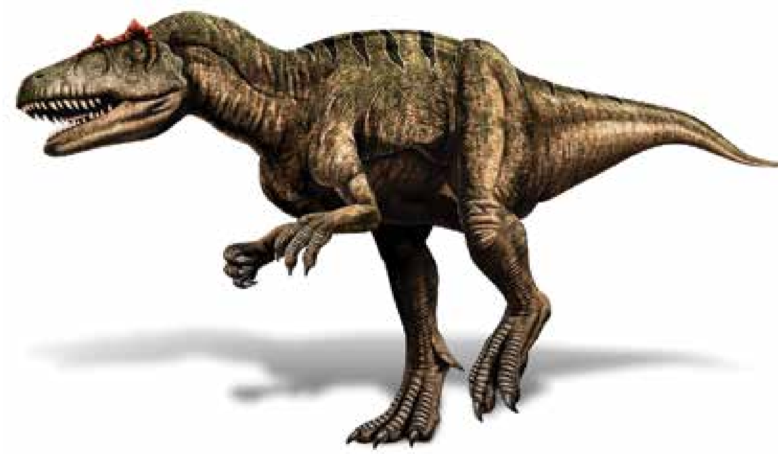
Educators! Dinosaur Data can also be used as reference material in your classroom. Dig around and use this information for math and statistics exercises as well as additional lessons in geography (map the locations) and history (create a timeline of the years).

Come face-to-teeth with the life-size juvenile and adult T. rex *at* Dinosaurs Unearthed*. Exhibition designers hand-carve the models and the installation crew hand sews the separate pieces together using suture needles.*

ALLOSAURUS

Order: Saurischia

Suborder: Theropoda



Name means	Different lizard
Pronunciation	AL-uh-SOR-us
Period	Late Jurassic
Location	North America: Colorado, Montana, New Mexica, Oklahoma, South Dakota, Utah, Wyoming; Europe: Portugal
Length	Up to 12 meters (39 ft)
Height	5 meters (16 ft)
Named in	1877

Quick Facts:

- A two-legged meat-eater, *Allosaurus* could open its jaws extra wide, like some modern snakes, to swallow huge chunks of meat.
- A fierce carnivore, *Allosaurus* used sharp, serrated teeth to slice through flesh.
- In the 1920s, at the Cleveland-Lloyd Quarry in Utah, the remains of 44 *Allosaurus* and several other dinosaurs were found together.

MICRORAPTOR

Order: Saurischia

Suborder: Theropoda

Name means	Small thief
Pronunciation	(Mie-krow-RAP-tor)
Period	Early Cretaceous –125 Mya
Location	Asia: China – Liaoning Province
Length	40 centimeters (16 in)
Weight	1 kg (2.2 lb)
Named in	2000

Quick Facts:

- Although it may have looked like a large bird, *Microraptor* was a theropod dinosaur.
- With sharp teeth and long feathers on its hind legs, which no modern bird has, *Microraptor* was an evolutionary experiment in preying from the air.
- A 2012 scientific paper revealed that not only did *Microraptor* have glossy, iridescent black feathers but that a specialized set of paired feathers at the end of the tail might be another clue that display and visual communication were very important factors in the early evolution of feather anatomy and color.

PROTOCERATOPS

Order: Ornithischia
Suborder: Ceratopsia

Name means	First-horned face
Pronunciation	proto-SER-uh-TOPS
Period	Late Cretaceous
Location	Asia: Mongolia
Length	1.5 - 2.5 meters (5 - 8 ft)
Named in	1923

Quick Facts:

- Although *Protoceratops* is nick-named as "first horned-face" it did not have the well-developed horns that are seen in other ceratopsids such as *Triceratops*.
- A nest was discovered in 2011 that contained the remains of 15 infants. The young *Protoceratops* were between 10 - 15 cm (4 - 6 in) in length.
- In 2011 scientists reexamined a *Protoceratops* fossil, originally found in 1965, and discovered that the dinosaur's footprint was preserved with the fossil. This is the only example of a footprint and a dinosaur being found together.

RUYANGOSAURUS (juvenile)

Order: Saurischia
Suborder: Sauropodomorpha

Name means	Ruyang lizard
Pronunciation	Roo-YAHNG-o-SOR-us
Period	Late Cretaceous
Location	Asia: China – Henan Province
Length	Over 30 meters (over 99 ft)
Height	Over 9 meters (over 30 ft)
Named in	2009

Quick Facts:

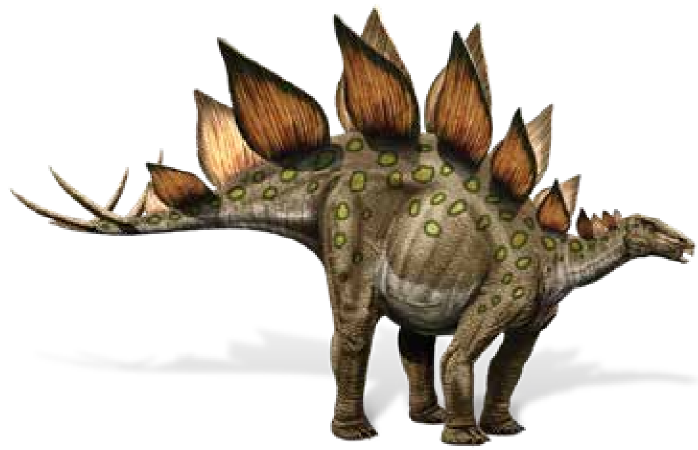
- A sauropod of the titanosaur group, *Ruyangosaurus* had a shorter neck and tail than earlier Jurassic sauropods like *Omeisaurus* and *Mamenchisaurus*.
- Like many titanosaurs, the skin of *Ruyangosaurus* was armored – covered in small bead-like scales.
- Discovered earlier at the same excavation site as *Ruyangosaurus,* paleontologists also found a slightly smaller sauropod, *Huanghetitan*. These were the first two dinosaurs to be discovered in Henan Province in 2006 - 2007, an area already well-known for dinosaur eggs.

STEGOSAURUS

Order: Ornithischia

Suborder: Thyreophora

Name means	Roof lizard
Pronunciation	STEG-o-sawr-us
Period	Late Jurassic
Location	North America: USA – Montana, Kansas, North Dakota, South Dakota, Nebraska, Wyoming, Colorado; Europe: Portugal
Length	9 meters (30 ft)
Height at hip	4 meters (13 ft)
Named in	1877



Quick Facts:

- The plates on its back made the *Stegosaurus* look larger to its enemy and may have also discouraged attack by predators.
- *Stegosaurus* had five toes on its front feet, but only three on its back feet.
- Because its brain was so tiny, *Stegosaurus* was probably one of the least intelligent dinosaurs.

TRICERATOPS

Order: Ornithischia

Suborder: Marginocephalia

Name means	Three-horned face
Pronunciation	try-SER-uh-TOPS
Period	Late Cretaceous
Location	North America: USA – Colorado, Montana, South Dakota, Wyoming; Canada – Alberta, Saskatchewan
Length	9 meters (30 ft)
Height	3 meters (10 ft)
Named in	1889

Quick Facts:

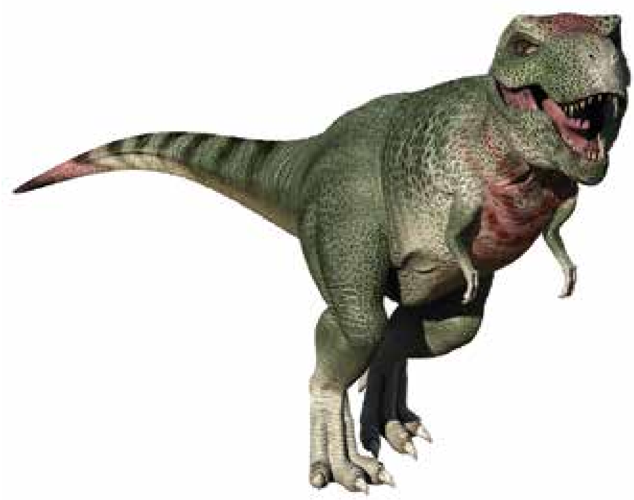
- The large neck frill on *Triceratops* probably helped keep its body temperature normal and protected it from predators like *Tyrannosaurus rex*.
- One *Triceratops* survived after a *Tyrannosaurus rex* bit off half of a horn!
- It's easy to look at *Triceratops* and see its resemblance to a modern rhinoceros, but they are not related. Rhinos are mammals.

TYRANNOSAURUS REX

Order: Saurischia

Suborder: Theropoda

Name means	King of the tyrant lizards
Pronunciation	tuh-RAN-uh-SOR-us recks
Period	Late Cretaceous
Location	North America: USA – Colorado, Montana, New Mexico, Wyoming; Canada – Alberta
Length	Up to 13 meters (43 ft)
Height at hip	4 meters (13 ft)
Named in	1905



Quick Facts:

- Usually it is impossible to know if a fossil came from a male or female, but one *Tyrannosaurus rex* was definitely a female; a leg bone contained a special inner layer only found in female birds.
- A *Tyrannosaurus rex's* lower jaw could deliver 50,000 newtons of force – the equivalent force needed to lift a big elephant!
- *T. rex* of all ages have been found together, which means this dinosaur was possibly not the solitary predator living alone, as is often shown.

TYRANNOSAURUS REX (juvenile)

Order: Saurischia

Suborder: Theropoda

Name means	King of the tyrant lizards
Pronunciation	tuh-RAN-uh-SOR-us recks
Period	Late Cretaceous
Location	North America: USA – Colorado, Montana, New Mexico, Wyoming; Canada – Alberta
Length	Up to 13 meters (43 ft) as an adult
Height at hip	4 meters (13 ft) as an adult
Named in	1905

Quick Facts:

- Although no fossil evidence has been found to date showing young *Tyrannosaurus rex* possessed feathers, other species of tyrannosaurids discovered in 2004 show the distinct coat of fibers which are precursors to feathers.
- This covering was shed before the animal reached adulthood. Feathers likely initially developed to regulate body temperature and became unnecessary over time as the dinosaur became larger and its body better able to meet its heating and cooling requirements.
- Juveniles were more lightly built than adults, with longer legs and a delicate skull. This meant their feeding strategy was different from the adult *T. rex*. They were unable to crunch through dense bones. Adults, with their fused nasal bones, could crunch through anything.

VELOCIRAPTOR

Order: Saurischia

Suborder: Theropoda

Name means	Swift thief
Pronunciation	(vuh-LOSS-ih-RAP-ter)
Period	Late Cretaceous – 75 Mya
Location	Asia: Mongolia
Length	2 meters (6.56 ft)
Height	0.5 meters (1.64 ft)
Named in	1924

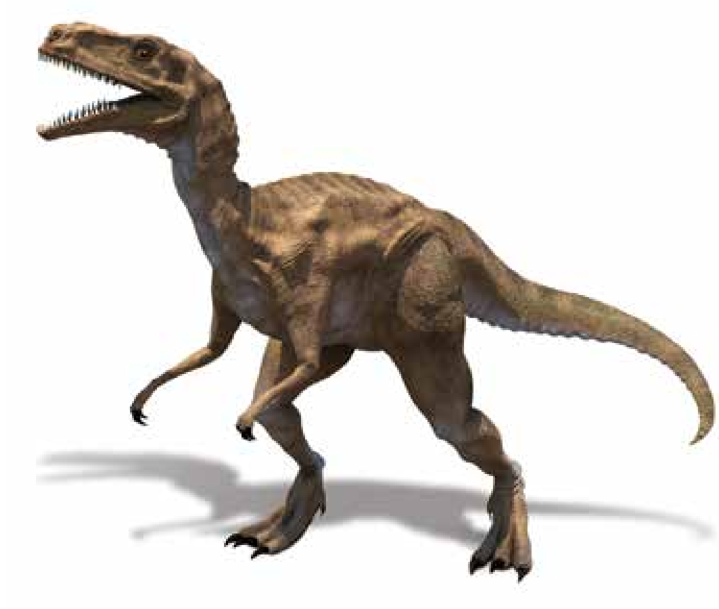
Quick Facts:

- In 2007 paleontologists found evidence of quill knobs on the forelimbs of *Velociraptor* which suggested the dinosaur bore modern-style wing feathers, with a rachis and vane formed by barbs.
- In popular culture *Velociraptor* is often portrayed as a pack animal but there is no fossil evidence to support this behavior.
- Evidence of predatory behavior is rare in the fossil record but a *Velociraptor* specimen was found locked in combat with its prey, *Protoceratops*.

YANGCHUANOSAURUS

Order: Saurischia

Suborder: Theropoda



Name means	Yang-chuan lizard
Pronunciation	yang-chew ON-uh-SOR-us
Period	Late Jurassic
Location	Asia: China – Sichuan Province
Length	10 meters (33 ft)
Height	4.5 meters (15 ft)
Named in	1978

Quick Facts:

- *Yangchuanosaurus* is the largest Late Jurassic predator ever found in China so far.
- By comparing the size of its brain to the weight of its body, *Yangchuanosaurus* seems to have been fairly intelligent for a dinosaur.
- This dinosaur lived in the same time and place as the giant sauropods *Omeisaurus* and *Mamenchisaurus*.

DISCOVERING DINOSAURS

Fascinating Facts

You can adapt these fun facts about dinosaurs for trivia contests, Dinosaur Fact-of-the-Day calendars, Jeopardy and Bingo games. They are divided into three categories. "Species Specifics" contains information about particular kinds of dinosaurs. "Finding Fossils" lists interesting facts about finding and studying fossils. "Dinosaur Domain" describes fascinating details about dinosaurs living and adapting in their world for millions of years.

Species Specifics

- Although *Stegosaurus* was about the size of a bus, it had a small head (the size of a horse's head) and a brain that was only the size of a walnut!
- *Ankylosaurus* was one of the last dinosaurs to go extinct, probably because of its heavy armor and slow metabolism.
- In 1925, *Allosaurus* was featured in the movie The Lost World, the first full-length dinosaur movie – making it the first movie-star dinosaur.
- Not all sauropods were gigantic behemoths like *Argentinosaurus* (30 - 36 meters, or 98 - 118 feet) or had incredibly long necks like *Mamenchisaurus*. Some, like *Magyarosaurus*, found in Romania in 2005, were "small" at only 5.3 meters (17 feet) long.
- One of the largest complete dinosaurs ever discovered was *Brachiosaurus* ("arm lizard") which was 82 feet (two large school buses) long and 42 feet (a 4 story building) tall.
- One of the most intelligent dinosaurs was *Troodon*. It had a brain the size of a mammal or bird of today, plus stereoscopic (binocular) vision and grasping hands.
- One of the smaller dinosaurs was only slightly larger than a chicken. *Compsognathus* ("pretty jaw") was 3 feet long and weighed about 6.5 pounds.
- The biggest carnivores were theropods from the Cretaceous Period, such as *Tyrannosaurus rex*.
- The dinosaur *Gasosaurus* was named for the gas company under construction in the area when it was discovered in the Dashanpu Quarry.
- Due to the discovery of melanosomes (these organelles found in animal cells are responsible for color) we now know that *Microraptor* was an iridescent black and that *Sinosauropteryx* had a rusty orange and white ringed tail.
- *Micropachycephalosaurus* has the longest name of any dinosaur. It means "tiny, thick-headed lizard."
- The fierce *T. rex* began life as a fuzzy, feathered baby.
- The first dinosaur to be named was *Megalosaurus*, in 1824 by Reverend William Buckland.
- When the first *Triceratops* was discovered, scientists classified it as something similar to a buffalo, not a dinosaur.
- *Mojoceratops,* a "new" species of ceratopsid, or horned-face dinosaur, was recently found mixed in with a collection of fossils from a similar-looking dinosaur at the American Museum of Natural History in New York City.

Finding Fossils

- Ancient traditional Chinese medicines that called for "dragon bones" were actually using the fossilized bones of a titanosaur sauropod from the early Late Cretaceous Period.
- In the 1970s, a fossil was found in the Gobi desert of a *Protoceratops* and a *Velociraptor* fighting.
- Over 700 different species of dinosaurs have been identified and named based on fossil evidence. However, paleontologists believe that there are many more new and different dinosaur species still to be discovered.

Mojoceratops

Velociraptor

- The Dashanpu Quarry in China may contain the single greatest concentration of dinosaur fossils ever found.
- Dinosaur fossils have been found in 35 US states and on every continent.
- In the 1800s, coprolite (fossilized dinosaur dung) was mined in England for fertilizer. During WWI, coprolite was used in the making of munitions.
- More *Allosaurus* fossils have been found than for any other dinosaurs so far.
- The first decade of the 21st century has seen rogue fossil hunters steal everything from a set of 30 theropod footprints in England to hundreds of eggs from China and Mongolia.
- The term dinosaur ("terrible lizard") was created by the English anatomist Sir Richard Owen in the early 1840's when fossil hunting was growing in popularity.
- The only dinosaurs we can know about are the ones that leave fossils, but fossilization is a very rare process.
- When the first dinosaurs lived, the Earth's land was formed into one big super continent called Pangaea, which is why we find fossils from the same dinosaurs on more than one continent.
- The first North American dinosaur fossils were found in 1854 in the Upper Missouri River. These fossils were a small collection of teeth.
- Only about 3% of dinosaur fossils found are from carnivores.

Dinosaur Domain

- Before dinosaurs first evolved about 230 million years ago, the dominant land reptiles were archosaurs ("ruling lizards") and therapsids ("mammal-like reptiles"). For the next 20 million years after the first dinosaurs appeared, the most fearsome reptiles were crocodiles, not dinosaurs.
- Dinosaurs and modern birds share over 90 anatomical features including the neck, wrist bones and breastbone.
- *Hadrosaur* nests have been found complete with fossils of babies. The babies have slightly worn teeth, suggesting that they were probably fed by their parents.
- *Hadrosaurs*, often called duck-billed dinosaurs, were the only dinosaurs to develop cheeks and they also had more teeth than any other dinosaurs.
- Most dinosaurs were herbivores, meaning that they ate plants.
- Sauropods had more phalanges (digits, like fingers or toes) on their "feet" than on their "hands."
- Some ankylosaurid dinosaurs were so heavily covered with armored plates that they even had armored eyelids.
- Some dinosaurs had replaceable teeth; when a tooth was lost or broken, another one grew in to take its place.
- Some scientists think that the growth rates of theropods show a pattern much closer to other animals that are warm-blooded, not cold-blooded.
- The biggest dinosaurs were sauropods – gigantic, slow-moving, small-headed herbivores from the Late Jurassic and Cretaceous Periods.
- Various dinosaurs lived on Earth for about 165 million years. Humans have been around for about 1 million years.

Microraptor

GLOSSARY

animatronics	Using technology to animate motorized models.
apex	Top-most, highest-ranking.
Appalachia	During the Cretaceous Period, the eastern area of the landmass that would become the continent of North America.
archosaurs	The “ruling reptiles” group including dinosaurs, crocodiles and pterosaurs.
avian	Bird-like.
binocular vision	The ability to maintain focus on an object with both eyes, creating a single visual image and indicating depth perception.
bi-pedalism	Walking on two feet; a form of terrestrial locomotion where an organism moves on its two rear limbs or legs. An animal that usually moves in a bi-pedal manner is known as a biped, meaning “two feet.”
bonebed	A layer of rock with a very large number of fossils often formed when floods or volcanic eruptions quickly overwhelmed groups of dinosaurs.
Bone Wars	A period of intense rivalry between two paleontologists (Edward Drinker Cope and Othniel Charles Marsh) at the end of the 19th century to see who could collect the most fossils and identify the most new species of dinosaurs.
carcass	Dead body of an animal.
carnivore	An animal that feeds on the flesh of other animals.
cervical	Pertaining to the neck.
Chicxulub Crater	Ancient impact crater beneath the Yucatan Peninsula in Mexico created approximately 65 million years ago, believed to have begun a series of global events and climate changes leading to the dinosaurs’ extinction.
cladistic analysis	Biological systematics that classify organisms into hierarchical groups, based on the branchings of different groups from a common ancestor.
Cleveland-Lloyd Quarry	A National Natural Landmark in the San Rafael Swell near Cleveland, Utah. It contains the densest concentration of Jurassic dinosaur fossils found thus far.
cold-blooded	Animals that rely upon the outside temperature to regulate their body temperature.
convergent evolution	When unrelated species develop similar biological traits; for example, wings in bats and birds, or facial horns in a *Rhinoceros* and *Triceratops*.
coprolite	Fossilized dinosaur dung.
Cretaceous Period	145 - 65 million years ago.
Dashanpu Quarry	A site in the Sichuan Province of China where many dinosaur fossils including seven species of theropods, ten species of sauropods, four stegosaurs and a pterosaur have been found.
digit	Finger or toe.
dinosaur	Literal meaning is “terrible lizard.” Dinosaurs, which lived millions of years ago, were one of several kinds of prehistoric reptiles that lived during the Mesozoic Era.

evolution	Change in the genetic composition of a population during successive generations as a result of natural selection of the genetic variation among individuals and resulting in the development of new species.
excavate	To dig in the earth carefully in order to find buried objects, such as skeletons.
extant	Still alive, not extinct.
extinct	The ceasing to exist of a species, such as a plant or animal, whose numbers declined to the point where the last member of the species died and no new members of the species could ever again be born. Species become extinct when they are unable to adapt to changes in the environment or compete effectively with other organisms.
field gear	Equipment needed by dinosaur hunters ranging from simple hand tools such as hammers, chisels and shovels to earth-moving equipment such as bulldozers and trucks.
field jackets	Plaster-soaked burlap “bandages” – much like a cast which protects a broken arm – that keep fragile fossil pieces together and stable during transport to the laboratory.
fossil	“Having been dug up.” The remains of a living thing which have been buried in the ground, replaced by minerals and turned to stone.
furcula	The “wishbone” found in birds, formed by the fusing of the two clavicles, which has also been found in theropods.
gastroliths	Stomach stones that aided with digestion in some herbivores; gizzard stones.
Gondwana	Large landmass formed from the continents that would become South America, Africa, Australia and Antarctica.
herbivore	An animal that eats plants.
holotype	The specimen or sample used in the original description of a species.
ichnite	Fossilized footprint.
Jurassic Period	200 - 145 million years ago.
juvenile	Young, not fully grown.
Laramadia	During the Cretaceous Period, the western area of the landmass that would become the continent of North America.
Laurasia	Large landmass formed from the continents that would become North America, Europe and Asia.
mammal	Any of a class of warm-blooded higher vertebrates that nourish their young with milk secreted by mammary glands and have the skin usually more or less covered with hair. This includes humans.
mass extinction	The process in which huge numbers of species die out suddenly. The dinosaurs (and many other species) became extinct, possibly because of an asteroid that hit the earth.
medullary bone	A type of soft tissue found in the leg bones of present-day female birds only during ovulation.
Mesozoic Era	This era (“The Age of Reptiles”) occurred from 250 to 65 million years ago. It is divided into the Triassic, Jurassic and Cretaceous Periods, when dinosaurs, mammals and flowering plants evolved.
Mya	Million years ago. Also can be written as “mya.”

natural selection	A process whereby helpful traits (those that increase the chance of survival and reproduction) become more common in a population while harmful traits become increasingly rare. Individuals with advantageous traits are more likely to survive and reproduce, resulting in more individuals of the next generation inheriting those traits.
nostrils	The holes in the nose through which air passes during breathing.
omnivore	An animal that feeds on everything.
ornithopod	Bird-hipped dinosaurs. All these dinosaurs were herbivores.
oviparous	Reproduction by producing eggs that hatch outside of the body.
paleontologist	A scientist who deals with the life of past geological periods as known by fossil remains.
Pangea	The global supercontinent formed during the Paleozoic Era, which eventually separated and formed the continents we recognize today.
permineralization	When mineral-rich groundwater permeates a cell or plant wall and deposits minerals in the spaces that once held gas or liquid in the living organism.
predator	An animal that hunts, catches and eats other animals (the prey).
prehistoric	The time before humans began to record events.
preparators	Lab workers who prepare fossils for future examination and use.
prey	An animal that is hunted and eaten by other animals.
protofeathers	"First feathers" or the filament-like precursors to feathers that some dinosaurs had.
pterosaur	"Winged lizards" who had an elongated fourth finger that supported a membranous wing. First evolved in the latter third of the Triassic Period and survived until the end of the Cretaceous. These animals were not dinosaurs but were closely related to both dinosaurs and crocodiles.
quadrupedalism	A form of animal locomotion with four limbs or legs. An animal that usually moves this way is known as a quadruped, meaning "four feet."
reptiles	A class of air-breathing scaly-bodied vertebrates including alligators and crocodiles, lizards, snakes, turtles and extinct related forms (like dinosaurs and pterosaurs) that lay eggs which are fertilized internally.
sauropod	Lizard-hipped/footed, quadruped dinosaurs, such as diplodocids, brachiosaurids and titanosaurs. These dinosaurs were herbivores and were some of the largest animals ever to live on land.
scute	A bony plate embedded in the skin, found on armored dinosaurs and on the legs of modern birds; made of the same keratin protein found in feathers.
sedimentary rock	Rock formed from layers of sediment like mud, silt and sand carried by water, ice and wind; it is a kind of rock where fossils are found.
serrated	Sharp and jagged, notched or saw-like.
snout	The nose, jaw and front part of the face on an animal's head.
theropod	Beast-footed dinosaurs including allosaurs, tyrannosaurs and oviraptors. All of these dinosaurs were carnivores.
trace fossils	Fossils of footprints, eggshells, nests and droppings.
trackways	Paths of footprint fossils.

Triassic Period	250 - 200 million years ago.
vertebrae	The bone segments in the spine.
Western Interior Seaway	During the Cretaceous Period, the shallow inland sea dividing the continent that would become North America.

NATIONAL CURRICULUM STANDARDS - STEM

Science

Grades K-4

- **SCIENCE AS INQUIRY:** Abilities necessary to do scientific inquiry
- **LIFE SCIENCE:** Life cycles of organisms
- **EARTH AND SPACE SCIENCE:** Changes in earth and sky
- **SCIENCE AND TECHNOLOGY:** Abilities of technological design; Understanding about science and technology
- **HISTORY OF NATURE AND SCIENCE:** Science as a human endeavor

Grades 5-8

- **SCIENCE AS INQUIRY:** Abilities necessary to do scientific inquiry
- **LIFE SCIENCE:** Diversity and adaptations of organisms
- **EARTH AND SPACE SCIENCE:** Earth's history
- **HISTORY AND NATURE OF SCIENCE:** Science as a human endeavor; History of science

Technology

1. Creativity and Innovation

c. use models and simulations to explore complex systems and issues.

3. Research and Information Fluency

b. locate, organize, analyze, evaluate, synthesize and ethically use information from a variety of sources and media.
d. process data and report results.

4. Critical Thinking, Problem Solving and Decision Making

b. plan and manage activities to develop a solution or complete a project.
c. collect and analyze data to identify solutions and/or make informed decisions.

Mathematics

Number and Operations

- Understand numbers, ways of representing numbers, relationships among numbers and number systems
- Understand meanings of operations and how they relate to one another
- Compute fluently and make reasonable estimates

Algebra

- Use mathematical models to represent and understand quantitative relationships

Geometry

- Apply transformations and use symmetry to analyze mathematical situations
- Use visualization, spatial reasoning and geometric modeling to solve problems

Measurement

- Understand measurable attributes of objects and the units, systems and processes of measurement
- Apply appropriate techniques, tools and formulas to determine measurements

Data Analysis and Probability

- Formulate questions that can be addressed with data and collect, organize and display relevant data to answer them
- Select and use appropriate statistical methods to analyze data

Process

- Reasoning and proof
- Connections

Geography

PHYSICAL SYSTEMS: Understand the physical processes that shape the patterns of Earth's surface.
THE USES OF GEOGRAPHY: Understand how to apply geography to interpret the past.