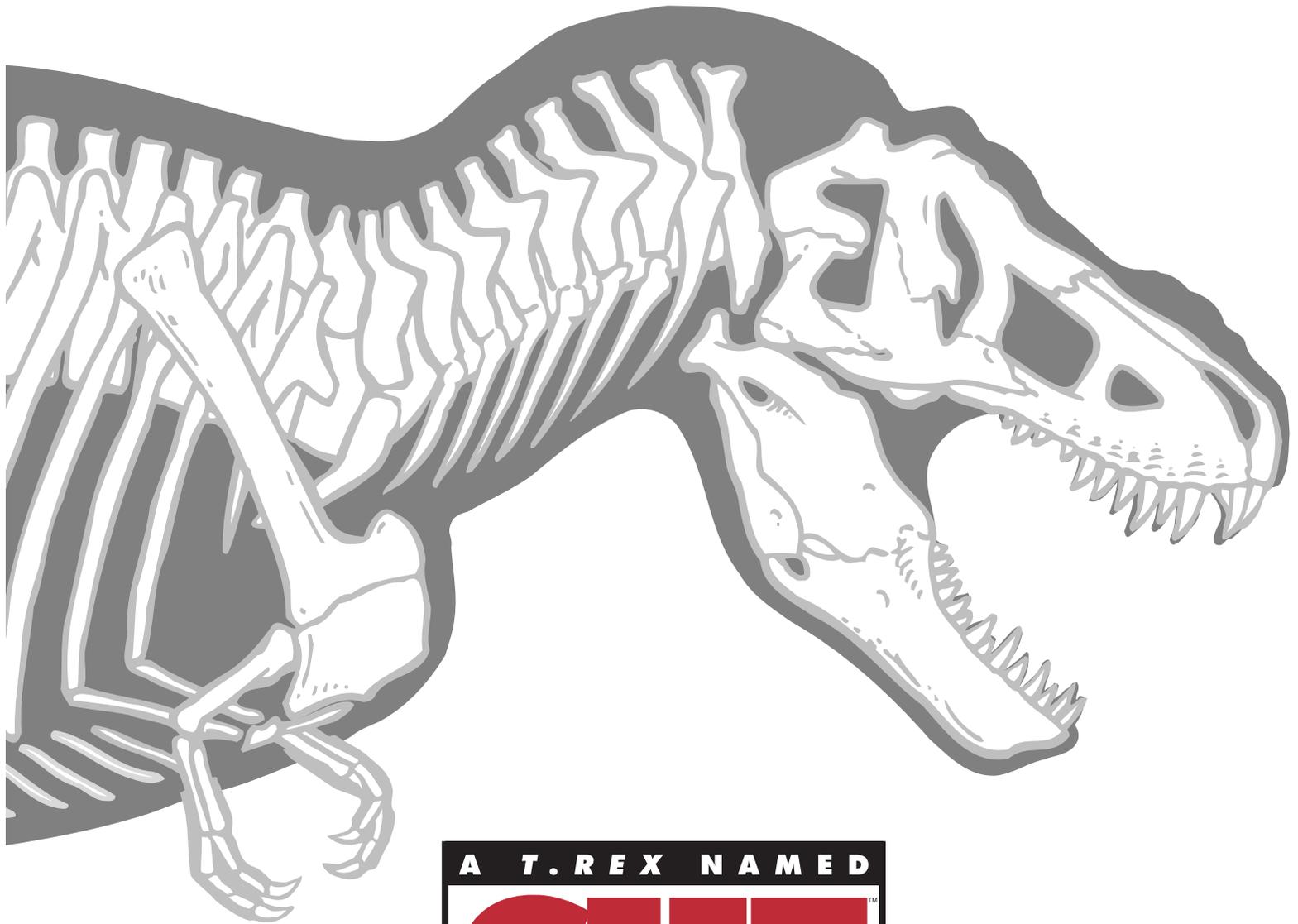


U N E A R T H I N G T H E
Secrets of Sue

The Sue Exhibition Educators' Guide



The Sue Educators' Guide is a product of The Field Museum Education Department

Reviewers

Darin Croft

Education Program Developer
Post-Doctoral Research Scientist

Mark Larson

Manager, Educational Partnerships and School Programs

Mary Ellen Munley

Former Director, Education and Outreach Programs

Jennifer Eagleton

Former Manager, Educational Media

Kirsten Ford

Curriculum Developer and Writer
Former Senior Media and Project Developer

John Frazier

Former Teacher Programs Coordinator

Dina Zissimopoulos

Former Chief Programming Officer, Education

Illustrations

Peter Arkle

Graphic Design

MobiGraphics, Inc.

Sue at The Field Museum is made possible by McDonald's Corporation.

A major sponsor of Sue is Walt Disney World Resort.

**The Elizabeth Morse Charitable Trust is the generous sponsor
of this exhibition at The Field Museum.**

Introduction

Imagine that you are a member of a five-person fossil expedition team working at a *Triceratops* excavation site. Early one morning a member of the team notices that one of the truck's tires went flat during the night. The team, tired of long, hot days working in the field, decides to call it a day and walk into town to get the tire repaired. You decide to stay behind.

You remember that something about the bluff in the distance caught your fancy earlier in the week. Compelled by curiosity and a sense of adventure, you head out on your own. After several hours of traversing rugged terrain, you arrive. Tired, you look up at the weathering bluff. At first, all you see is crumbling sandstone. Scanning the rubble at the bottom of the hillside, you catch a glimpse of what you have been looking for – fossilized bone fragments.

Hoping to find more bone, you eagerly look up. You catch your breath as your eyes lock on several large vertebrae and the end of a huge femur. Your mind begins to spin as your brain processes this visual information. A shout of excitement escapes your lips as you realize "I've just found a *Tyrannosaurus rex* fossil!"

Does this story sound too good to be true? This "story" is exactly what happened to Sue Hendrickson. In 1990 she discovered Sue, the largest, most complete, and best preserved *Tyrannosaurus rex* ever found. This moment of discovery is just the beginning of Sue the *T. rex*'s amazing story. Experts at The Field Museum have been working tirelessly so that the Museum can uncover and share this story with the world. Now turn the page, and learn Sue's story by engaging in a scientific expedition of your own.

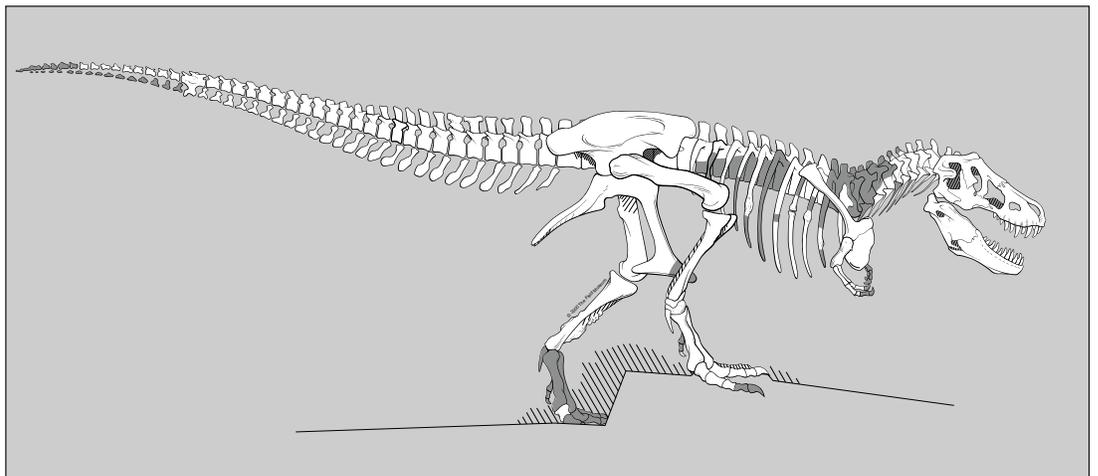


Table of Contents

| | |
|--|---------|
| I. Using the Educators' Guide | |
| A. Guide Format | 3–4 |
| B. Guide Topics and Activities | 5–6 |
| C. Activity Time Requirements | 7–8 |
| D. Student Introduction | 9 |
| II. Activities | |
| A. Discovery and Excavation | |
| 1. Finding Sue: Where should I look? | 11–20 |
| 2. Excavation Extravaganza | 21–38 |
| B. Preparation Activities | |
| 1. Fossil Facelift | 39–46 |
| 2. How can Sue be in more than one place? | 47–54 |
| C. Research Activities | |
| 1. What are observation, theory, and speculation? | 55–63 |
| 2. <i>Tyrannosaurus</i> Theories | 65–72 |
| 3. Anatomy 101 | 73–81 |
| D. Exhibition Activities | |
| 1. Sue in the Flesh: A portrait of fact, theory, and speculation | 83–92 |
| III. In The Halls | |
| A. Background Information | 93–98 |
| B. Activities | |
| 1. A Strand in Time | 99–103 |
| 2. Puzzling Pelvis | 105–113 |
| 3. What is your hypothesis? | 115–121 |
| IV. Careers in Science: The People Behind Sue | 123 |
| V. Glossary | 125–127 |
| VI. Resources | 129–145 |
| VII. Appendix | 145–147 |

Using the Guide

Using the Educators' Guide

Using the story of Sue to captivate students' imagination, the Educators' Guide takes fourth-through eighth-grade students on an interactive exploration of uncovering a *Tyrannosaurus rex*. This expedition will engage students in the scientific process by:

- **providing students unique access to Sue, the largest, most complete, and best preserved *Tyrannosaurus rex* ever discovered;**
- **providing students with hands-on activities that enable them to investigate by making observations, developing hypotheses, questioning assumptions, testing ideas, and coming to conclusions; and**
- **introducing students to careers in science by highlighting the wide professional expertise involved in the Sue project.**

In addition, the ***In The Halls*** section of the Educators' Guide provides general information on dinosaurs, geologic time, and fossils as well as three activities that can be used for a K-8 grade audience. These activities, which can be used in the classroom or the Museum, are simpler and less involved than the rest of the activities in the Guide. Therefore, they provide younger students who may not be ready to engage in an in-depth study an opportunity to interact and enjoy Sue. They will prepare these students for using the activities in the rest of the Guide when they are older.



Guide Format

This section introduces you to the layout of the Educators' Guide. Take a few minutes to familiarize yourself with how the activities are structured. For your convenience, all activities in the Guide follow the same basic format. The Teacher Section for each activity, which is printed on gray paper, consists of the following: Background, Activity Description, National Science Standards, Illinois State Standards, Objectives, Materials, Procedure, Preparation, Suggestions, and Investigation Data Sheet Answers. The Student Section for each activity, which is printed on white paper, includes the following: Background, Activity Description, Objectives, Materials, Procedure, and Investigation Data Sheet.

Background:

Each activity in this Guide tells part of Sue's Story. The Background Information provides detailed information about Sue. You may either distribute copies of the Background Information for students to read or read and discuss the Background Information during class.

Activity Description:

The Activity Description provides a brief overview of the activity.

National Science Standards:

Activities in the Educators' Guide were designed to help teachers meet National Science Standards. Each activity outlines which National Science Standards it fulfills. Most states use the National Science Standards to develop state science curriculum standards. For more information about the National Science Education Standards, call 800-624-6242 or 202-334-3313 in the Washington Metropolitan Area. You can also view information about National Science Education Standards online at: <http://www.nap.edu/readingroom/books/nses/html/>.

Illinois State Standards:

In addition to the National Science Standards, the Guide provides an overview to which Illinois State Standards the activities fulfill. For more information about the Illinois State Standards, contact the Illinois State Board of Education, Standards and Assessment Division, at 217-782-4823. You can also view information about Illinois State Standards online at: <http://www.isbe.state.il.us/ils/standards.html>.

Note: If you are a Chicago Public School teacher, refer to the appendix for Chicago Public School Standards.

Objectives:

Each activity focuses on specific educational objectives. The Objectives state what students will learn from the activity. For convenience, this section is subdivided into concept and skill objectives.

Materials:

Some activities require special materials. Each activity was designed to make use of readily available, inexpensive materials. This list of materials specifies what is needed for the activity. Feel free to make substitutions.

Procedure:

Frequently, an activity consists of several steps. This section instructs students on how to work through the activity.

Preparation:

Some activities require you to prepare materials ahead of time for the activity. This section provides detailed preparation instructions.

Suggestions:

This section provides you with suggestions that might be helpful as you use the activity.

Investigation Data Sheet:

Every activity includes an Investigation Data Sheet. The Investigation Data Sheet facilitates student thinking and learning. It asks students to record data and respond to questions. When applicable, the Guide includes answers to questions asked on the Investigation Data Sheet.

Extension Activities:

These are additional activities that you may use to enhance student learning.

Guide Topics and Activities

Students will learn about Sue’s journey to The Field Museum by completing activities in four topic areas: Discovery and Excavation, Preparation, Research, and Exhibition and Display.

Discovery and Excavation:

The first step in Sue’s journey to The Field Museum was the fieldwork—her discovery and excavation. The discovery and excavation section introduces students to the following two concepts: how to find fossils in the field and how to remove fossils from the field.

Activity 1: Finding Sue: Where should I look?

Using a stratigraphic column and a geologic map, students learn how scientists choose an area to survey for fossils. Students use this information to develop hypotheses about where in a given area they would and would not look for dinosaur fossils.

Activity 2: Excavation Extravaganza

Students conduct a fossil excavation from start to finish. After making observations and a site map, students hypothesize about where they think fossils are located. Based on their hypotheses, students choose a location and start hunting for fossils. Upon discovery of bones, students create a bone map and record detailed information about their find as they remove the fossil.

Preparation

After making the long sojourn from South Dakota to The Field Museum, Sue underwent extensive work before her skeleton could be studied and put on display. The Preparation section introduces students to the following three major concepts: how fossils are prepared, why fossils need to be copied, and how fossils are copied.

Activity 1: Fossil Facelift

Students make hypotheses about how to remove matrix from a fossil without damaging the fossil. Based on their hypotheses, students use a variety of tools to remove a matrix material from their fossil. After cleaning their fossil, students come to a conclusion regarding which method of preparing fossils is the best.

Activity 2: How can Sue be in more than one place?

Students are challenged to make a copy of an object that they can share with classmates. Using a variety of materials and techniques, students formulate and test different methods of replicating an object.

Research

Sue offers scientists many opportunities to learn more about dinosaurs, specifically about *Tyrannosaurus rex*. The Research section introduces students to ongoing Sue research as they learn the following concepts: understanding the terms observation, theory, and speculation; and understanding the relationship between making observations and formulating a theory.

Activity 1: What are observation, theory, and speculation?

Students use ongoing scientific research about Sue to understand the differences among observation, theory, and speculation.

Activity 2: *Tyrannosaurus rex* Theories

There are many unanswered questions about Sue. Students use information about crocodiles and birds, which share a common ancestor with *Tyrannosaurus rex*, to formulate theories that address these questions.

Activity 3: Anatomy 101

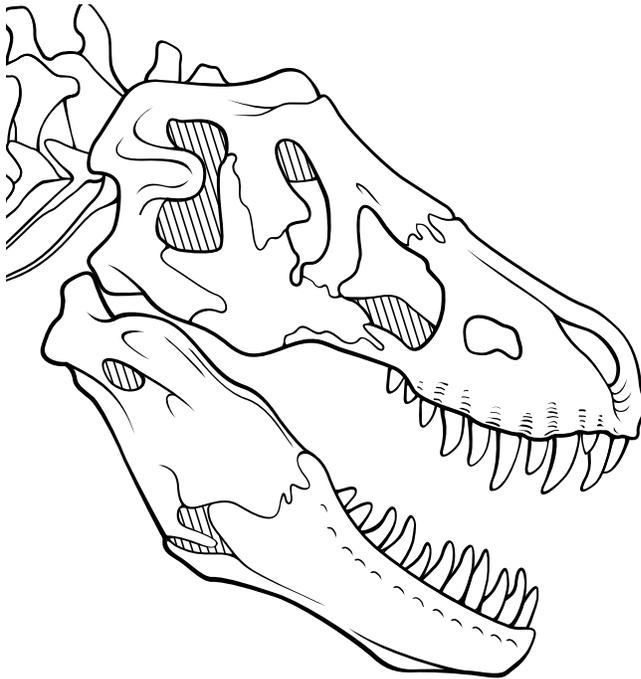
Using an anatomy guide that provides information about the major bones found in *Tyrannosaurus rex*, students identify what kinds of bones (i.e. vertebra, pelvis, femur, etc.) they excavated during the Excavation Extravaganza activity. In addition to identifying bones, students research similarities and differences between the bones they discovered and Sue's bones.

Exhibition and Display

To share Sue with the public, the Museum puts her bones and information from ongoing research on display. This section introduces students to how a fossil is put on display and to the variety of people from diverse career backgrounds necessary to make this happen.

Activity 1: Sue in the Flesh

Using factual information about Sue and theories that scientists are currently researching, students speculate about what Sue looked like when she lived during the Late Cretaceous.



Activity Time Requirements

| Activities | Total Class Time | Homework |
|--|--|---|
| Finding Sue | 45 min to 1 hr | 20 min—Students complete Investigation Data Sheet. |
| Extension Activity: Introducing Observation and Hypothesis | 30 to 45 min—Use with students before using the activity Excavation Extravaganza | |
| Excavation Extravaganza Day 2 | 45 min to 1 hr—Students make initial observations, make a site map, and respond to #1–3 on their Investigation Data Sheet. | 20 min—Students use their observations and site map to respond to #4–6 on their Investigation Data Sheet. |
| Excavation Extravaganza Day 3 | 45 min to 1 hr—Students review Bone Map instructions and begin excavation. | |
| Excavation Extravaganza Day 4 | 45 min to 1 hr—Students finish excavation and create a class bone map. | 20 min—Students use their data to respond to #7–9 on their Investigation Data Sheet. |
| Fossil Facelift | 45 min to 1 hr | 20 min—Students finish their Investigation Data Sheet. |
| How can Sue be in more than one place? Day 1 | 30 to 45 min—Students make initial observations and respond to #1 on their Investigation Data Sheet. | 20 min—Students respond to #2 on their Investigation Data Sheet. |
| How can Sue be in more than one place? Day 2 | 45 min to 1 hr—Students make copies of their object. | 20 min—Students respond to #3–5 on their Investigation Data Sheet. |
| What are observation, theory, and speculation? | 45 min to 1 hr | 20 min—Students finish their Investigation Data Sheet. |
| Tyrannosaurus Theories | 45 min to 1 hr—Students are preferably in a library so they can access resource materials. | 20 min—Students finish their Investigation Data Sheet. |
| Anatomy 101 | 45 min to 1 hr | 20 min—Students finish their Investigation Data Sheet. |
| Extension Activity: | 2 to 3 hrs | 20 min—Students read handouts. |
| Sue in the Flesh Day 1 | Distribute Sue Information and the Investigation Data Sheet. | 20 min—Students finish their Investigation Data Sheet. |
| Sue in the Flesh Day 2 | 45 min to 1 hour—Students create drawings of Sue. | 1+ hr—Students compile information for exhibition. |

Need help deciding which activities to use? Consider the following expedition combinations:

Expedition 1: eleven days

- Excavation Extravaganza
- Fossil Facelift
- How can Sue be in more than one place?
- Anatomy 101
- Fossil Exhibition

Expedition 2: seven days

- Finding Sue
- Fossil Facelift
- How can Sue be in more than one place?
- What are observation, theory, and speculation? **or** *Tyrannosaurus* Theories
- Sue in the Flesh

Expedition 3: four days

- Finding Sue
- What are observation, theory, and speculation? **or** *Tyrannosaurus* Theories
- Sue in the Flesh

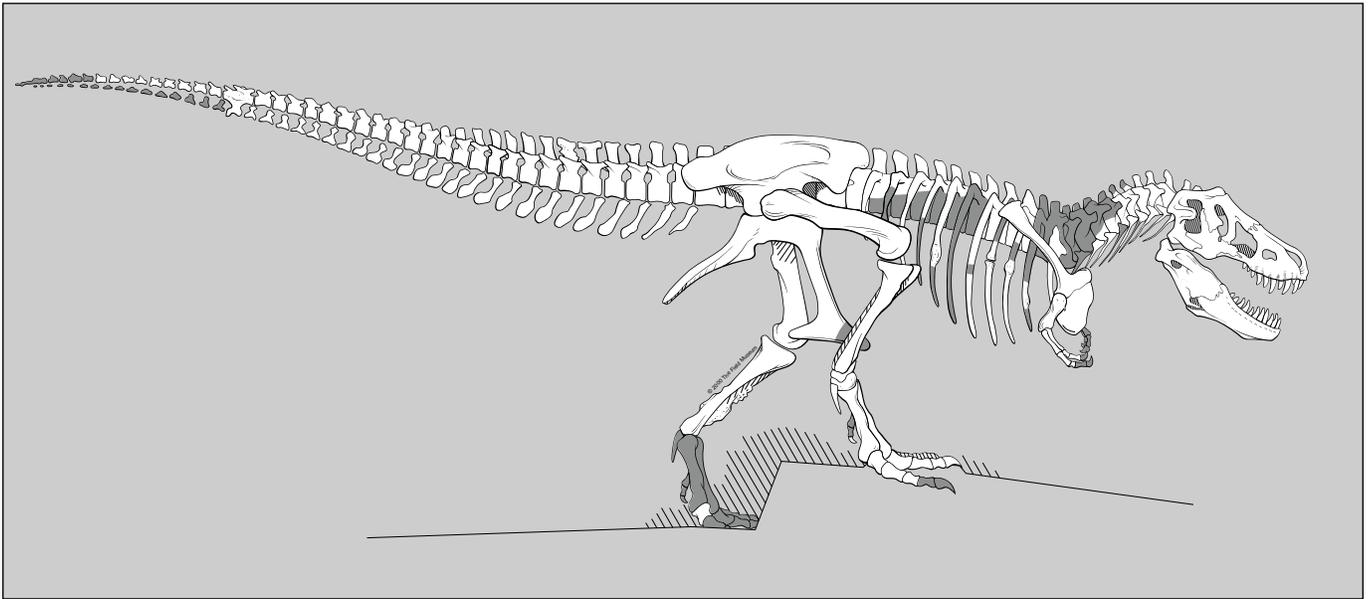
Expedition 4: two days

- Sue in the Flesh

Do not limit yourself to the proposed expeditions. There are many other possible combinations of activities. For example, if you are planning a field trip to view Sue either at The Field Museum or in the "A *T. rex* named Sue" traveling exhibition, you may want to incorporate activities from the ***In the Halls*** section of the Guide into your lesson plans.

Student Introduction

Imagine walking into a museum and coming face to face with a *Tyrannosaurus rex*. As you examine the forty-two-foot-long frame, questions race through your mind: How was this gigantic dinosaur discovered and by whom? How were the fossils removed from the ground? How were the individual bones prepared before they were put on display? What have scientists learned about *T. rex* by studying this fossil? Stop imagining, and meet Sue, the largest, most complete, and best preserved *Tyrannosaurus rex* ever discovered.



Get ready to embark on a fossil expedition. Over the course of the next few days, you and your expedition team are going on an interactive exploration of uncovering a *Tyrannosaurus rex*. By the end of your adventure, you will have learned about Sue and all the work that went into putting her on display at The Field Museum in Chicago. Depending on the length of your trip, your expedition may include learning how to find fossils in the field, choosing an excavation site, conducting a fossil excavation, preparing fossils, engaging in scientific research, and putting your fossil on display. Excited? Let's go!

Discovery & Excavation

Finding Sue: Where should I look?

Background:

Sue's Discovery

During the summer of 1990, Sue Hendrickson became an excavation volunteer for the Black Hills Institute of Geological Research (a paleontological supply house that locates, excavates, and prepares fossils). Sue and the rest of the expedition crew were working on a *Triceratops* fossil excavation when one of the truck's tires went flat. While most of the crew went into town to get the tire fixed, Sue stayed behind to check out a bluff that she had noticed several days earlier.

After hiking out to the eroding bluff, she explored the area. Within a few minutes, she noticed several fossil bones that had rolled down the incline. She looked up and spotted several vertebrae and a large femur sticking out of the face of the bluff. She identified them as bones of a large carnivorous dinosaur and suspected that they might be from a *Tyrannosaurus rex*. She was right, and the fossilized skeleton was later named "Sue" in Hendrickson's honor.

Luck or Science?

It is easy to attribute Sue Hendrickson's discovery of Sue to luck or chance. To a certain extent she was incredibly lucky because *T. rex* fossils are rare. In fact, to date only twenty-two have been found. On the other hand, hard work also played a significant role in her huge discovery because people must know where to look.

When fossil hunters, like Sue Hendrickson, go into the field, they start by asking the following question: if we want to find dinosaur fossils, where should we look? Studying geology and previous fossil finds helps narrow the search to a large-scale area likely to contain dinosaur fossils. To find a specific type of fossil, like a dinosaur, it is necessary to look in rocks from the Mesozoic Era, 250 to 65 million years ago. While older and younger rocks may contain fossils, they would not contain a single dinosaur fossil. Older rocks pre-date the existence of dinosaurs, and younger rocks were deposited after the extinction of dinosaurs. It is also important to look in rocks, like sandstone, which are conducive to fossil preservation. Therefore, to find the right kinds of rock, fossil hunters might use geologic maps, which provide detailed information about the age, composition, and location of rock formations.

Once they choose a large-scale area, fossil hunters survey the locality for small-scale sites where erosion has exposed the specific rock of the correct age. While finding a *T. rex* fossil is rare, Sue Hendrickson increased her odds by looking in the right kinds of rock (the Hell Creek Formation) of the correct age (Late Cretaceous, 67-65 million years ago) at an exposed locale of a bluff.

Activity Description:

Using a stratigraphic column, which provides geologic information about the composition (what rock is made of) and order of strata (layers of sedimentary rock), and a geologic map, students learn how scientists choose an area to survey for fossils. Students use this information to develop hypotheses about where in a given area they would and would not look for dinosaur fossils.

National Science Standards:**Content Standard A: Science as Inquiry**

Abilities necessary to do scientific inquiry

- Design and conduct a scientific investigation
- Use appropriate tools and techniques to gather, analyze, and interpret data
- Develop descriptions, explanations, predictions, and models using evidence
- Think critically and logically to make the relationships between evidence and explanations

Understandings about scientific inquiry

Content Standard C: Life Science

Diversity and adaptations of organisms

Content Standard D: Earth and Space Science

Structure of the earth system

Earth's history

Illinois State Standards:**English Language Arts****State Goal 1: Read with understanding and fluency.**

A. Apply word analysis and vocabulary skills to comprehend selections.

- Late Elementary –2b
- Middle School –3b

C. Comprehend a broad range of reading materials.

- Late Elementary –2a, 2f
- Middle School –3a, 3f

State Goal 3: Write to communicate for a variety of purposes.

C. Compose ideas in writing to accomplish a variety of purposes.

- Late Elementary –2a
- Middle School –3a

State Goal 4: Listen and speak effectively in a variety of situations.

A. Listen effectively in formal and informal situations

- Late Elementary –2b
- Middle School –3b

Mathematics

State Goal 10: Collect, organize and analyze data using statistical methods; predict results; and interpret uncertainty using concepts of probability.

A. Organize, describe and make predictions from existing data.

- Late Elementary –2c
- Middle School –3c

B. Determine, describe and apply the probabilities of events.

- Late Elementary –2b
- Middle School –3b

Science

State Goal 11: Understand the process of scientific inquiry and technological designs to investigate questions, conduct experiments and solve problems.

A. Know and apply the concepts, principles and processes of scientific inquiry.

- Late Elementary –2a, 2b, 2d, 2e
- Middle School –3a, 3c, 3f, 3g

State Goal 12: Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences.

C. Know and apply concepts that describe the features and processes of the Earth and its resources.

- Late Elementary –2b
- Middle School –3b

State Goal 13: Understand the relationships among science technology and society in historical and contemporary contexts.

B. Know and apply concepts that describe the interaction between science, technology and society.

- Late Elementary –2c
- Middle School –3c

Objectives:

Content:

1. Students learn geologic information.
2. Students learn about how scientists choose an excavation site.

Skills:

1. Students make and record observations.
2. Students make hypotheses.
3. Students use stratigraphic columns and geologic maps to determine where to find dinosaur fossils.

Materials:

Stratigraphic Column
Geologic Map
Investigation Data Sheet
Colored pens, pencils, or crayons

Procedure:

1. Follow the instructions on the Stratigraphic Column, and answer questions #1–3 on the Investigation Data Sheet.
2. Follow the instructions on the geologic map handout, and answer questions #4–6 on the Investigation Data Sheet.

Preparation:

1. Make copies of the Background, Stratigraphic Column, Geologic Map, and Investigation Data Sheet for each student.
2. Familiarize yourself with the activity. Read through the Stratigraphic Column, Geologic Map, and Investigation Data Sheet answers.

Suggestions:

1. If you have access to a video that explains the process of fossilization, consider showing it before using this activity. It will help students understand how a dinosaur fossil came to be in the ground in the first place. It also will highlight the requisite conditions for fossil formation. This knowledge builds a strong foundation for students to understand that specific types of fossils are found in the right kind of rock of the correct age.
2. Consider having students work in small groups of 3–4 students on this activity.
3. When students have completed the activity, collect their Investigation Data Sheet. Use the provided answers to assess their work.

Investigation Data Sheet Answers:

1. Which layers did you color *blue*? What led you to believe they would contain dinosaurs?
The Sandstone portion of the Cretaceous layer and Triassic layer. These layers are the right age and the right kind of rock to contain dinosaur fossils.
2. Which layers did you color *green*? What led you to believe they would not contain dinosaurs?
The Paleocene layer. This layer was deposited after dinosaurs went extinct at the end of the Cretaceous. It is too young to contain dinosaur fossils.
3. Which layers did you color *yellow*? What led you to believe they would not contain dinosaurs?
The Paleozoic layer, Jurassic layer, and the shale section of the Cretaceous layer. All of these layers were deposited in the ocean. There were no marine dinosaurs.
4. Which sites are worth surveying for dinosaur fossils? Explain.
Sites B and D. Both of these sites contain the right kind of rock of the right age.
5. Which sites are not worth surveying for dinosaur fossils? Explain.
Both Sites A and G are in the wrong kind of rock. It is not the right type nor the right age. Sites C and F are the right age, but they are ocean deposits so they are not the right type of rock. Site E is too young to contain fossils, and it is an ocean deposit.
6. If you wanted to look for a *Tyrannosaurus rex*, like Sue, which sites would you look at? Explain.
*Site D is the only site where there is a possibility of finding a *T. rex* fossil. This site has the right type of rock (sandstone) of the right age (late Cretaceous).*

Finding Sue: Where should I look?

Background:

Sue's Discovery

During the summer of 1990, Sue Hendrickson became an excavation volunteer for the Black Hills Institute of Geological Research (a paleontological supply house that locates, excavates, and prepares fossils). Sue and the rest of the expedition crew were working on a *Triceratops* fossil excavation when one of the truck's tires went flat. While most of the crew went into town to get the tire fixed, Sue stayed behind to check out a bluff that she had noticed several days earlier.

After hiking out to the eroding bluff, she explored the area. Within a few minutes, she noticed several fossil bones that had rolled down the incline. She looked up and spotted several vertebrae and a large femur sticking out of the face of the bluff. She identified them as bones of a large carnivorous dinosaur and suspected that they might be from a *Tyrannosaurus rex*. She was right, and the fossilized skeleton was later named "Sue" in Hendrickson's honor.



The bluff in the distance is where Sue Hendrickson found Sue—the largest, most complete, and best preserved *Tyrannosaurus rex* ever discovered. This bluff contains the right kind of rock (the Hell Creek Formation) of the correct age (Late Cretaceous, 67–65 million years ago) to find a *T. rex* fossil. Photograph provided courtesy of Black Hills Institute of Geological Research, Inc.

Luck or Science?

It is easy to attribute Sue Hendrickson's discovery of Sue to luck or chance. To a certain extent she was incredibly lucky because *T. rex* fossils are rare. In fact, to date only twenty-two have been found. On the other hand, hard work also played a significant role in her huge discovery because people must know where to look.

When fossil hunters, like Sue Hendrickson, go into the field, they start by asking the following question: if we want to find dinosaur fossils, where should we look? Studying geology and previous fossil finds helps narrow the search to a large-scale area likely to contain

dinosaur fossils. To find a specific type of fossil, like a dinosaur, it is necessary to look in rocks from the Mesozoic Era, 250 to 65 million years ago. While older and younger rocks may contain fossils, they would not contain a single dinosaur fossil. Older rocks pre-date the existence of dinosaurs, and younger rocks were deposited after the extinction of dinosaurs. It is also important to look in rocks, like sandstone, which are conducive to fossil preservation. Therefore, to find the right kinds of rock, fossil hunters might use geologic maps, which provide detailed information about the age, composition, and location of rock formations.

Once they choose a large-scale area, fossil hunters survey the locality for small-scale sites where erosion has exposed the specific rock of the correct age. While finding a *T. rex* fossil is rare, Sue Hendrickson increased her odds by looking in the right kinds of rock (the Hell Creek Formation) of the correct age (Late Cretaceous, 67–65 million years ago) at an exposed locale of a bluff.

Activity Description:

Using a stratigraphic column, which provides geologic information about the composition (what rock is made of) and order of strata (layers of sedimentary rock), and a geologic map, students learn how scientists choose an area to survey for fossils. Students use this information to develop hypotheses about where in a given area they would and would not look for dinosaur fossils.

Materials:

Stratigraphic Column
Geologic Map
Investigation Data Sheet
Colored pens, pencils, or crayons

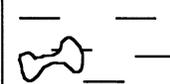
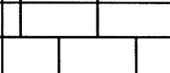
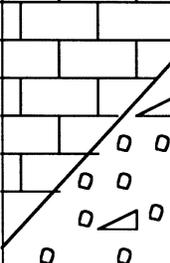
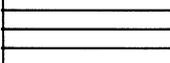
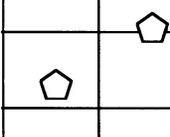
Procedure:

1. Follow the instructions on the Stratigraphic Column, and answer questions #1–3 on the Investigation Data Sheet.
2. Follow the instructions on the geologic map handout, and answer questions #4–6 on the Investigation Data Sheet.

Finding Sue

Stratigraphic Column

This chart is a stratigraphic column of rocks. It provides geologic information about the composition (what rock is made of) and the order of strata (layers of sedimentary rock). Use the stratigraphic column to think about which type of rock is the right type to contain dinosaur fossils. Also keep these two simple rules about dinosaurs in mind as you work on this activity: 1) Dinosaurs lived during the Mesozoic Era, 250 to 65 million years ago; and 2) Dinosaurs lived on land. They did not have wings to fly or fins to swim.

| Time (mya) | Rock Layer | Description |
|-------------------|---|--|
| Paleocene 65 |  | Mudstone—flood plain deposit Contains mammal fossils  |
| Cretaceous 144 |  | Sandstone—river deposit |
| |  | Shale—deep ocean deposit Contains ammonites, mosasaurs, and plesiosaurs  |
| Jurassic 206 |  | Chalk—ocean deposit Contains marine reptiles  |
| Triassic 250 |  | Sandstone—river deposit |
| Paleozoic 540 |  | Limestone—shallow ocean deposit Contains shells  |

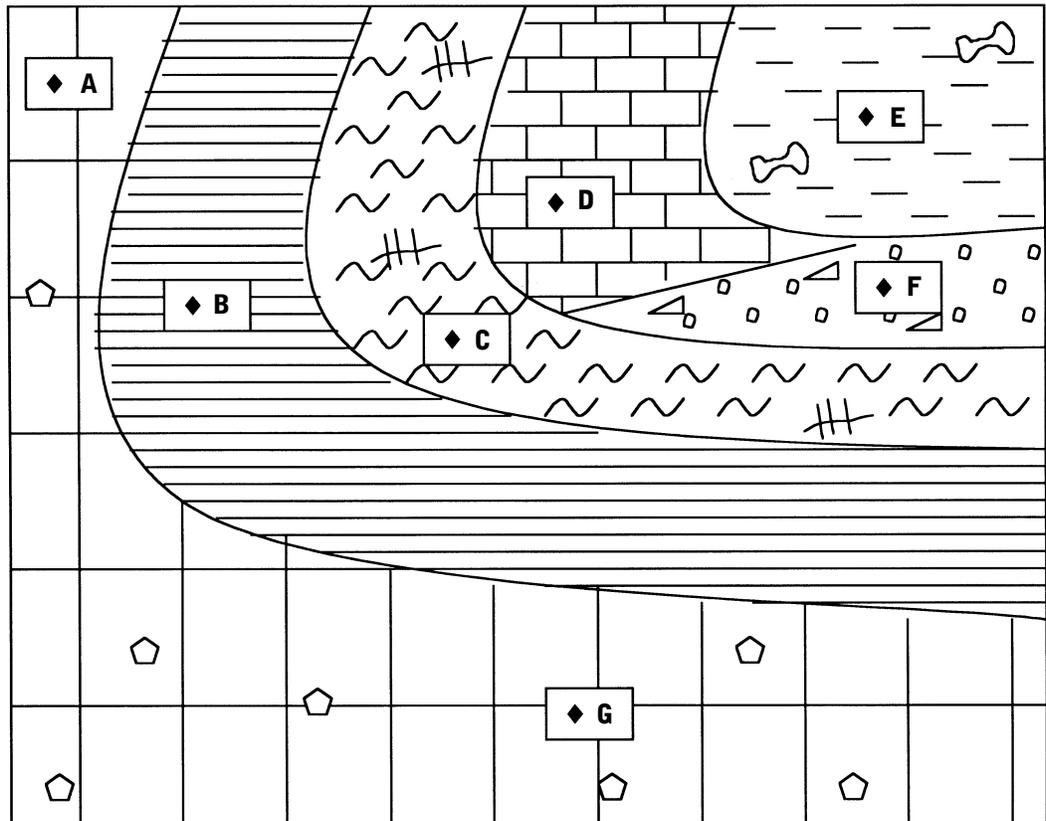
Instructions:

1. Examine each layer of the stratigraphic column, and read its description.
2. Color layers that could include dinosaur fossils **blue**.
3. Color layers that are too young to contain dinosaur fossils **green**.
4. Color layers that do not contain dinosaur fossils because they were deposited under an ocean **yellow**.
5. Answer questions #1–3 on the Investigation Data Sheet.

Finding Sue

Geologic Map

This is a geologic map. It shows what types of rocks are located in a given geographical area. Apply what you learned from the stratigraphic column to figure out where in this region you would look for dinosaur fossils. Notice that dinosaur fossil hunters have chosen several potential excavation sites, labeled A–G. Your job is to evaluate whether or not each site might contain dinosaur fossils.



Instructions:

1. Examine the geologic map. Notice where each type of rock you learned about with the stratigraphic section handout is exposed.
2. Color areas **blue** on this map that correspond to the stratigraphic layers you colored **blue**.
3. Color areas **green** on this map that correspond to the stratigraphic layers you colored **green**.
4. Color areas **yellow** on this map that correspond to the stratigraphic layers you colored **yellow**.
5. Answer questions #4–6 on the Investigation Data Sheet.

Finding Sue

Investigation Data Sheet

Stratigraphic Section:

1. Which layers did you color *blue*? What led you to believe they would contain dinosaur fossils?

2. Which layers did you color *green*? What led you to believe they would not contain dinosaur fossils?

3. Which layers did you color *yellow*? What led you to believe they would not contain dinosaur fossils?

Geologic Map:

4. Which sites are worth surveying for dinosaur fossils? Explain.

5. Which sites are not worth surveying for dinosaur fossils? Explain.

6. If you wanted to look for a *Tyrannosaurus rex*, like Sue, at which sites would you look? Explain.

Excavation Extravaganza

Background:

When Sue Hendrickson discovered bones sticking out of an eroded bluff, all she could see were several large vertebrae (back bones) and the end of a huge femur (thigh bone). She immediately identified them as the bones of a large carnivorous dinosaur and suspected that they might be from a *Tyrannosaurus rex*. When the other members of the fossil expedition team returned, Sue told them about her discovery. Peter Larson, one of the directors of the Black Hill Institute, confirmed that the fossils were from a *T. rex*, and they were named “Sue” in Hendrickson’s honor.

Anxious to find out if more of the *T. rex* skeleton was buried in the hillside, the team began to excavate. As the team unearthed Sue, it was important for them to keep track of each bone that they exposed. Therefore, they mapped out the site so they could record detailed information about the position, orientation, and identity of each bone. In addition to this bone map, some scientists now also use a digital camera to record more information, such as the date, specimen number, scale, location, and rock type. No matter how field researchers do it, this detailed information must be preserved.

While the bones themselves are an invaluable source of information, they tell only part of Sue’s story. Information about the rock type, orientation, and position of the bones also documents information about how Sue died and what happened to her skeleton after death. For example, a complete, fully-articulated skeleton suggests a rapid burial at or soon after the time of death. Missing bones might be the result of predators or scavengers carrying them away from the site.

Activity Description:

Students work in teams to conduct a fossil excavation from start to finish. After making observations and a site map, students hypothesize about where they think fossils are located. Based on their hypotheses, students choose a location and start hunting for fossils. Upon discovery of bones, students create a bone map and record detailed information about their find as they remove the fossil.

National Standards:

Content Standard A: Science as Inquiry

Abilities necessary to do scientific inquiry

- Design and conduct a scientific investigation
- Use appropriate tools and techniques to gather, analyze, and interpret data
- Develop descriptions, explanations, predictions, and models using evidence
- Think critically and logically to make the relationships between evidence and explanations

Understandings about scientific inquiry

Content Standard C: Life Science

Diversity and adaptations of organisms

Content Standard D: Earth and Space Science

Structure of the earth system

Earth's history

Illinois State Standards:

English Language Arts

State Goal 1: Read with understanding and fluency.

A. Apply word analysis and vocabulary skills to comprehend selections.

- Late Elementary –2b
- Middle School –3b

C. Comprehend a broad range of reading materials.

- Late Elementary –2a, 2f
- Middle School –3a, 3f

State Goal 3: Write to communicate for a variety of purposes.

C. Compose ideas in writing to accomplish a variety of purposes.

- Late Elementary –2a
- Middle School –3a

State Goal 4: Listen and speak effectively in a variety of situations.

A. Listen effectively in formal and informal situations

- Late Elementary –2b
- Middle School –3b

B. Speak effectively using language appropriate to the situation and audience.

- Late Elementary –2b
- Middle School –3b

Mathematics

State Goal 7: Estimate, make and use measurements of objects, quantities and relationships and determine acceptable levels of accuracy.

A. Measure and compare quantities using appropriate units, instruments and methods

- Late Elementary –2a
- Middle School –3a

B. Estimate measurements and determine acceptable levels of accuracy.

- Late Elementary –2a
- Middle School –3a

C. Select and use appropriate technology, instruments and formulas to solve problems, interpret results and communicate findings.

- Late Elementary –2a
- Middle School –3a

State Goal 10: *Collect, organize and analyze data using statistical methods; predict results; and interpret uncertainty using concepts of probability.*

A. Organize, describe and make predictions from existing data.

- Late Elementary –2c
- Middle School –3c

C. Determine, describe and apply the probabilities of events.

- Late Elementary –2b
- Middle School –3b

Science

State Goal 11: *Understand the process of scientific inquiry and technological designs to investigate questions, conduct experiments and solve problems.*

A. Know and apply the concepts, principles and processes of scientific inquiry.

- Late Elementary –2a, 2b, 2d, 2e
- Middle School –3a, 3c, 3f, 3g

State Goal 12: *Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences.*

E. Know and apply concepts that describe the features and processes of the Earth and its resources.

- Late Elementary –2b
- Middle School –3b

State Goal 13: *Understand the relationships among science technology and society in historical and contemporary contexts.*

A. Know and apply concepts that describe the interaction between science, technology and society.

- Late Elementary –2c
- Middle School –3c

Objectives:

Concepts:

1. Students learn how fossils are excavated.
2. Students learn how to record data at an excavation site.

Skills:

1. Students make and record observations.
2. Students make and test a hypothesis and then draw a conclusion.
3. Students make a Site Map.
4. Students make a Bone Map.

Materials:

- Field Notebook – includes an Investigation Data Sheet, Site Map, Bone Data Sheet, and Bone Map
- Metric ruler

- Pencil
- Dental tools
- Tiny paintbrushes or toothbrushes
- Toothpicks
- Magnifying glasses
- Camera (optional)

Procedure:

1. Respond to #1 on your Investigation Data Sheet.
2. Begin the excavation by spending time observing the site. Record your observations in your Investigation Data Sheet, #2–3.
3. Following instructions in the Site Map, map the excavation site.
4. Based on your observations and site map, where do you think you will find fossils? Record your answer in your Investigation Data Sheet, #4–6.
5. Select a quadrangle for your team to excavate.
6. Carefully remove matrix by using the tools your teacher has made available.
7. Keep an eye out for fossils. Do not rush. Rushing could damage the bone.
8. When your team discovers a fossil, follow the instructions in your Bone Map and Bone Data Sheet.
9. Record information about each bone in your Bone Map and Bone Data Sheet.
10. When you are finished excavating your site, clean up.
11. Respond to #7–9 on your Investigation Data Sheet.

Preparation:

Part A: Fossils

Materials:

- A whole chicken: Contact your local butcher or poultry processing plant to see if you can get an entire chicken, including the head and the feet. Or buy a whole chicken from your local grocery store, and prepare it using the following materials:
- Heat source
- Oven
- A large metal container
- Foil
- Baking tray
- Dishwasher detergent
- Bleach
- Water

Instructions: (total time = eight hours*)

1. Remove the meat from the bones by placing the chicken in the metal container and covering it with water. Place on heat source, and bring to a boil. Let the chicken boil for twenty to thirty minutes until the meat is cooked and easily comes off the bones. Allow the chicken to cool, and then remove as much of the meat as you can, and rinse off the bones.
2. Place the bones into the metal container. Cover them with a solution of dishwasher detergent and hot water. Use $\frac{1}{8}$ cup of detergent per gallon of water. Place on a heat source, and simmer for two hours. Drain, rinse, and then remove any remaining non-bone material. Repeat once.
3. Remove the grease from the bones by soaking them in a bleach and hot water solution. Use $\frac{1}{4}$ cup of bleach per gallon of water. Allow the bones to soak for an hour, or heat and boil them for half-an-hour.
4. Drain and rinse twice.
5. After the bones are degreased, place them on a baking tray covered in foil. Bake the bone in a 200-degree oven for two hours. Alternatively, you can set them in the sun for a few hours.

***Note:** If you do not have the time or resources to prepare bones for this activity, replace the fossils with another object. A good alternative to bones is little plastic animal figures. They are inexpensive and easy to find in toy stores. Often, you can buy plastic dinosaurs. Using toy dinosaurs would allow you to ask your students to conduct research on their dinosaur. For example, if they found a *Triceratops*, then they could identify and learn more about it. Of course, the trade-off is that the dig is less realistic.

Part B. Excavation Site

Materials:

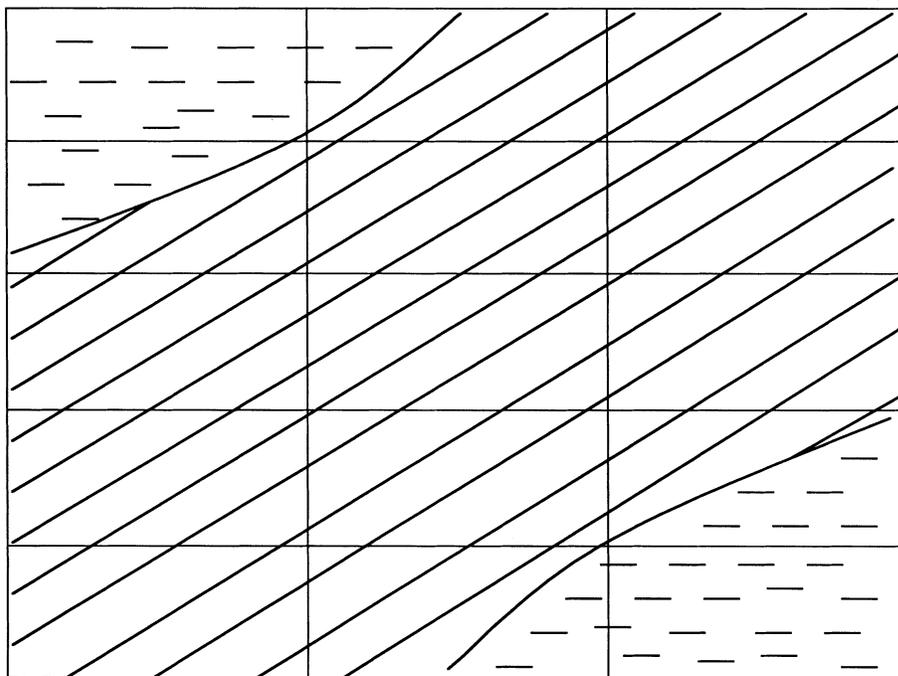
- Excavation Site Diagram
- 15 half-gallon milk or juice containers – You need at least one container for every team of 2–3 students. You may want to ask students to bring these containers from home a week before the lab.
- Soil – A large bag of potting soil should be sufficient to fill the **Stratum A** containers (see diagram) $\frac{3}{4}$ full.
- Soil/Sand – This material should look noticeably different, for example a different color, from the other soil. You need enough to fill **Stratum B** containers (see diagram) $\frac{3}{4}$ full.
- Plaster of paris
- Large bucket

Instructions:

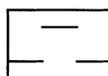
1. Prepare the containers. Placing the containers on their side, cut away the top panel. The result will be an open box. Note that if you have your students do this step in class, you will reduce your preparation time.
2. Prepare the bones. After they dry, break some of the chicken bones. Often, when fossils are discovered, they are broken because of the way the organism died or the way they were fossilized.
3. Prepare the soil for **Batch A**. Pour the soil into the bucket, and then add all of the bones to the soil. Add water until the mixture takes on a mud-like consistency. Add a small amount of plaster powder, no more than a cup. As the soil dries, the plaster will help harden the soil around the fossils. This mixture simulates the hard matrix that surrounds real fossils. Stir until the plaster and bones are mixed in.
4. Prepare the soil for **Batch B**. Pour the soil, which looks noticeably different from the soil you used for **Batch A**, into a container without any bones. Add water until the mixture takes on a mud-like consistency. Add a small amount of plaster, no more than $\frac{1}{2}$ cup. Stir until the plaster is mixed in.
5. Arrange the containers in a grid (*see diagram*). With a permanent marker, label each container A–L. Make sure that you write the label somewhere on the container where it is visible when the whole site is laid out. If you write it in the same location on every container, then you can use the label to orient the containers.
6. Pour **Batch A** into the containers that correspond to **Stratum A** on the diagram.
7. Pour **Batch B** into the containers that correspond to **Stratum B** on the diagram.
8. Notice that a few of the containers require you to add a combination of soil mixtures. Carefully pour each soil mixture into the mixed containers as indicated on the diagram.
9. Allow the excavation site to dry.
10. Now you are ready to start the lab.

Diagram:

This diagram will help you set up the excavation site for this activity in a way that is easy and will maximize student learning. Notice on the diagram that two different strata (layers of sedimentary rock) are exposed. Your students will be able to deduce that they are different strata because they look different. The purpose of having two different strata at the site is to provide students with the opportunity to gather evidence and then to make and test a hypothesis about where fossils are located at the excavation site. Students will observe that fossils are exposed in **Stratum A**, which corresponds to the soil mixture to which you added chicken bones. They also will notice that there are no exposed fossils in **Stratum B**, which corresponds to the soil mixture without chicken bones. Therefore, they can postulate that they are more likely to find fossils in **Stratum A** and should choose to excavate in a container that is compositionally **Stratum A**.



Key:



Stratum A – does not contain fossils



Stratum B – does contain fossils

Suggestions:

1. Make copies of Background and the Investigation Data Sheet, Site Map, Bone Data Sheet, and Bone Map for each student.
2. Start off the excavation activity by making sure your students know what an observation is. If you have already taught this concept in class, your students can start by defining observation and then making and recording observations on their *Investigation Data Sheet*. If not, you should introduce your students to the concept of observations. Use the extension activity on the next page called Introducing Observation and Hypothesis to familiarize your students with this concept.
3. Ask your students to spend a few minutes observing the excavation site.
4. After they have had a chance to observe the site, ask students to record their observations on the Investigation Data Sheet. As they make observations, help students to think about questions like: What does the exposed rock look like? Is the rock the same everywhere? Do I see any fossils?
5. Once the students are finished recording observations, they are ready to draw the Site Map of the excavation site.
6. The students should be able to follow the instructions to draw the Site Map. You will know if they are on the right track if their maps look like the Excavation Site Diagram in the teacher preparation pages.
7. For homework, or classwork if you have the time, ask students to use their observations and the Site Map to develop a hypothesis about which sections of the site are likely to contain fossils and which are not. Students should record their hypothesis on the Investigation Data Sheet. Students need to be familiar with the term hypothesis before they can complete this assignment. Use the extension activity Introducing Observation and Hypothesis to familiarize your students with this concept.
8. Ask students to read the instructions on the Bone Map and Bone Data Sheet before starting the excavation.
9. You may wish to circulate around the room as students are excavating fossils to make sure that students are recording data on their Bone Map and Bone Data Sheet as they remove fossils.
10. If you want your students to do the Fossil Facelift activity (pg.39) using bones they remove from this excavation, have each team remove at least one fossil without cleaning off all the material.
11. After students finish excavating, you may want to work as a class to construct a large class Bone Map using team maps for each quadrangle.
12. Decide whether or not you want to conduct any of these activities: Fossil Facelift (pg. 39); How can Sue be in more than one place? (pg. 47); and Fossil Exhibition (pg. 75). If you are planning to do any of these activities, save the bones your students unearthed from Excavation Extravaganza. Give each team a plastic bag in which to store fossils. Keep track of the fossils by writing the quadrangle name on the bag in permanent marker.

Extension Activity: Introducing Observation and Hypothesis

Students need to know that an *observation* is information that they collect from the world around them by using their five senses: sight, touch, smell, taste, and hearing. Challenge your students to define an observation by asking them how they gather information about a specific object that you show them. Use an everyday object from your classroom like a book bag or poster. Encourage your students to make detailed and descriptive observations. You might want to introduce your students to *qualitative observation*. This kind of observation includes specific descriptions like the book bag is a dark olive green. You can also introduce them to *quantitative observation*. This kind of observation includes numbers or measurements like there are five lizards and two moths on the poster.

An easy way for your students to practice is to have each student make observations of an object of their choice. Then have your students exchange their observations with another member of the class. Ask the students if they can visualize the object based on the observations. This activity will allow you to introduce your students to the term hypothesis. An *hypothesis* is a prediction based on observations. Often students confuse making a hypothesis with guessing. Guessing implies that students are not really basing their choice on evidence or logical reasoning. An hypothesis, on the other hand, is based on gathering and using information to formulate an idea that can be tested. Ask your students to formulate and record hypotheses about the identity of the classroom object by using the observations they were given. They can test their hypotheses by asking the student who made the observations whether or not they are correct. This activity gives students an opportunity to practice making and testing hypothesis. It also illustrates the importance of making detailed observations. Students will discover that is easier to make hypotheses when they have detailed observations.

Excavation Extravaganza

Background:

When Sue Hendrickson discovered bones sticking out of an eroded bluff, all she could see were several large vertebrae (back bones) and the end of a huge femur (thigh bone). She immediately identified them as the bones of a large carnivorous dinosaur and suspected that they might be from a *Tyrannosaurus rex*. When the other members of the fossil expedition team returned, Sue told them about her discovery. Peter Larson, one of the directors of the Black Hill Institute, confirmed that the fossils were from a *T. rex*, and they were named "Sue" in Hendrickson's honor.

Anxious to find out if more of the *T. rex* skeleton was buried in the hillside, the team began to excavate. As the team unearthed Sue, it was important for them to keep track of each bone that they exposed. Therefore, they mapped out the site so they could record detailed information about the position, orientation, and identity of each bone. In addition to this bone map, some scientists now also use a digital camera to record more information, such as the date, specimen number, scale, location, and rock type. No matter how field researchers do it, this detailed information must be preserved.

While the bones themselves are an invaluable source of information, they tell only part of Sue's story. Information about the rock type, orientation, and position of the bones also documents information about how Sue died and what happened to her skeleton after death. For example, a complete, fully-articulated skeleton suggests a rapid burial at or soon after the time of death. Missing bones might be the result of predators or scavengers carrying them away from the site.



Sue Hendrickson is hard at work exposing fossilized bone at the Sue excavation site. Photo provided courtesy of Black Hills Institute of Geological Research, Inc.

Excavation Extravaganza

Activity Description:

Students work in teams to conduct a fossil excavation from start to finish. After making observations and a site map, students hypothesize about where they think fossils are located. Based on their hypotheses, students choose a location and start hunting for fossils. Upon discovery of bones, students create a bone map and record detailed information about their find as they remove the fossil.

Materials:

- Field Notebook – includes an Investigation Data Sheet, Site Map, Bone Data Sheet and Bone Map
- Metric ruler
- Pencil
- Dental tools
- Tiny paintbrushes or toothbrushes
- Toothpicks
- Magnifying glasses
- Camera (optional)

Procedure:

1. Respond to #1 in your Investigation Data Sheet.
2. Begin the excavation by spending time observing the site. Record your observations in your Investigation Data Sheet, #2–3.
3. Following instructions in the Site Map, map the excavation site.
4. Based on your observations and site map, where do you think you will find fossils? Record your answer in your Investigation Data Sheet, #4–6.
5. Select a quadrangle for your team to excavate.
6. Carefully remove matrix by using the tools your teacher has made available.
7. Keep an eye out for fossils. Do not rush. Rushing could damage the bone.
8. When your team discovers a fossil, follow the instructions in your Bone Map and Bone Data Sheet.
9. Record information about each bone in your Bone Map and Bone Data Sheet.
10. When you are finished excavating your site, clean up.
11. Respond to #7–9 in your Investigation Data Sheet.

Excavation Extravaganza

Site Map

When scientists find a fossil in the field, one of the first things they do is draw a map of the site. Mapping out the area allows scientists to keep track of exactly where they found each fossil and where it is located and oriented in relation to other bones. The information that is collected at the excavation site is important because it tells part of the story of the fossil. Therefore, we need to record it at our site just like scientists do at their sites.

Instructions:

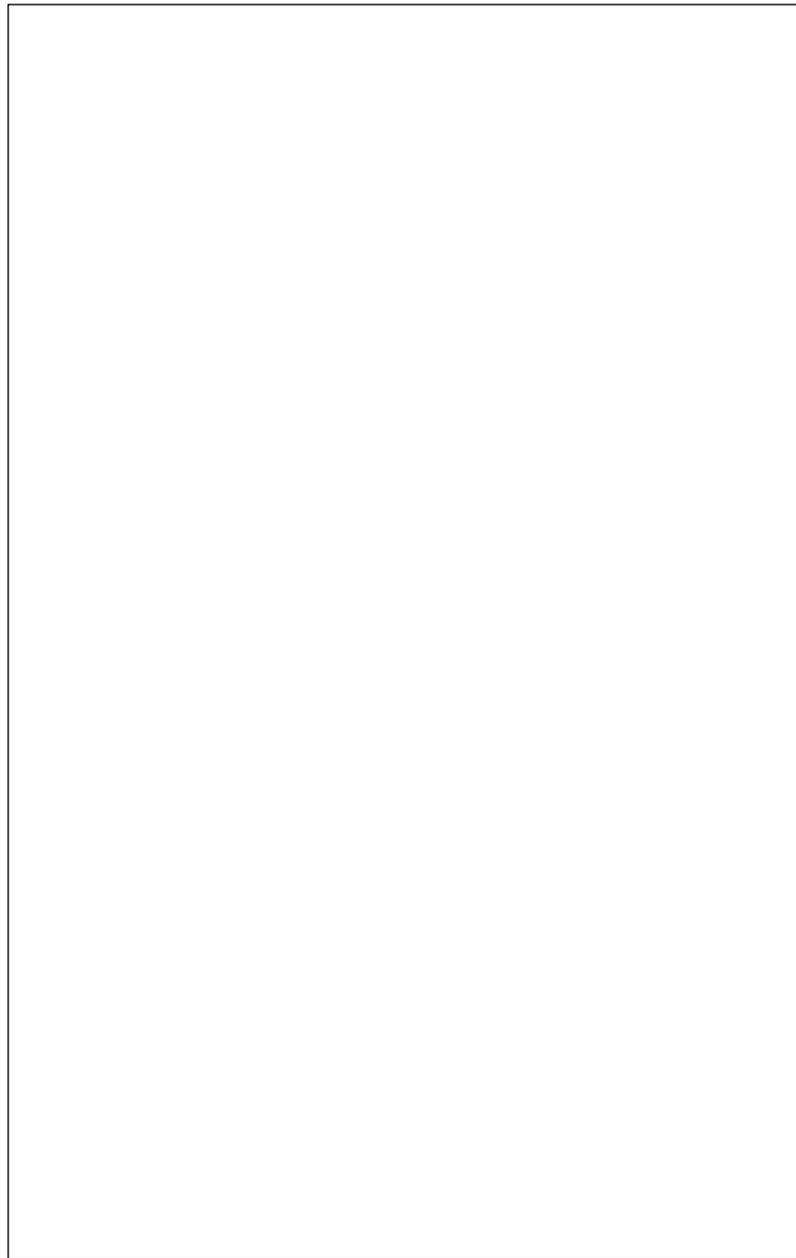
1. Label each rectangle on your Site Map, which represents one container, so it corresponds to a specific section of the excavation site.
2. Using your observations as a starting point, draw in distinguishing features. For example, if you notice that the rock type does not look the same everywhere, specify where you observed each type of rock. Choose a color to represent each type of rock that you observe, and use that color to fill in areas where you observe that particular rock type. Create a key to explain any colors or symbols you use on your map.
3. Remember that you are looking for fossils, so any bones you observe should be treated as distinguishing features. Make sure to note the exact position of each exposed fossil. Keep in mind that you want your Site Map to be drawn to scale.

| | | |
|--|--|--|
| | | |
| | | |
| | | |
| | | |
| | | |

Excavation Extravaganza

Bone Map

This box represents your team's section of the excavation site. As you find a bone, record its exact location on this Bone Map by drawing in the bone. Keep in mind that you want your site map to be drawn to scale. In addition, you should write the specimen number on the actual bone and on the drawing of the bone.



Excavation Extravaganza

Bone Data Sheet

When the excavation team uncovers a fossil at an excavation site, they record detailed information about its orientation and position. In order to keep track of all the fossils at one site, the team assigns each bone a unique specimen number. Therefore, as you find each bone, give it a specimen number. Each fossil you uncover will have a unique two-part number. The first part of the specimen number is the name of the site section you are excavating. The second part of the specimen name is the order in which you discovered the fossil. For example, if you are working in Section A and you have just found your third bone, you would label it A-3. In addition to numbering your bone, you need to record observations about the bone. These observations should include the dimensions of the fossil and other distinguishing features.

| Section Name –Bone # | Observations |
|----------------------|--------------|
| | |
| | |
| | |
| | |
| | |
| | |

Excavation Extravaganza: Field Notebook

Investigation Data Sheet

1. What is an observation?

2. After spending a few minutes examining the excavation site, record detailed and descriptive observations.

3. Which quadrants contain exposed fossils? Be specific.

4. What is an hypothesis?

5. Based on your observations, develop an hypothesis about where in the excavation site, besides areas where you actually see exposed fossils, you may uncover fossils.

6. Which observations led you to your hypothesis?

7. Do the results of your excavation support or contradict your hypothesis?

8. Based on observations and data collected during the excavation, form a conclusion about where fossil hunters should look for fossils in an area containing rock layers similar to those at your excavation site.

9. After completing your excavation, what questions do you still have about how a fossil excavation is conducted?

Preparation

Fossil Facelift

Background:

Once Sue arrived at The Field Museum, the most difficult part of the excavation process, preparation of Sue's bones for study and display, got underway. When Sue's bones arrived at the Museum, they were still mostly covered by rocky material called matrix. Each bone had to be carefully removed from the matrix without being damaged.

Most of Sue's bones were taken to the McDonald's Fossil Preparation Laboratory located on the second floor of The Field Museum. Some of Sue's tail, ribs, and hind legs were taken to another laboratory located in DinoLand U.S.A., part of Disney's Animal Kingdom at Walt Disney World Resort. Both of these "prep" labs are open to public viewing so people just like you who are visiting The Field Museum or Animal Kingdom can see how fossils are prepared.

Fossil preparators, people who are trained to clean fossils and get them ready for display and research, use a variety of tools and equipment to prepare and clean fossils. At first, preparators use an air scribe (a mini jackhammer) to remove chunks of rock from areas where there is no danger of damaging the bone. When they need to remove matrix closer to the actual bone, they use an air abrasive tool. This tool, which is very similar to the tool the dentist uses to dry your teeth, is a mini sandblaster that blows baking soda. This gentle abrasive removes dirt and other matrix from the fossils. While this equipment makes the preparation a bit easier, all of the delicate work is done by hand using equipment like dental scrapers, tiny brushes, and pins. Because fossils are often very delicate and brittle, they are then coated with a hardening liquid that soaks in and protects the fragile bone.

Activity Description:

Students use a variety of tools to clean an object by removing matrix.

National Standards:

Content Standard A: Abilities Necessary to do Scientific Inquiry

Abilities necessary to do scientific inquiry

- Design and conduct a scientific investigation
- Communicate scientific procedures and explanations

Content Standard F: Science in Personal and Social Perspectives

Science and technology in society

Content Standard G: History and Nature of Science

Science as a human endeavor

Illinois State Standards:

English Language Arts

State Goal 1: Read with understanding and fluency.

A. Apply word analysis and vocabulary skills to comprehend selections.

- Late Elementary –2b
- Middle School –3b

C. Comprehend a broad range of reading materials.

- Late Elementary –2a, 2f
- Middle School –3a, 3f

State Goal 3: Write to communicate for a variety of purposes.

C. Compose ideas in writing to accomplish a variety of purposes.

- Late Elementary –2a
- Middle School –3a

Science

State Goal 11: Understand the process of scientific inquiry and technological designs to investigate questions, conduct experiments and solve problems.

D. Know and apply the concepts, principles and processes of scientific inquiry.

- Late Elementary –2a, 2b, 2d, 2e
- Middle School –3a, 3c, 3f, 3g

Objectives:

Concepts:

1. Students learn how fossils are prepared.
2. Students learn about a career in science, that of fossil preparator.

Skills:

1. Students make and record observations.

Materials:

- Matrix covered object
- Investigation Data Sheet
- Tiny brush
- Dental tools
- Toothpicks
- Magnifying glass

Procedure:

1. Working with a partner, gather the materials for this activity.
2. Before you start to remove matrix from your object, respond to #1–2 on the Investigation Data Sheet.
3. Using the hypothesis you developed, begin removing matrix from the object.
4. After you have completely removed the object from the matrix, respond to #3–6 on the Investigation Data Sheet.

Preparation:

If you conducted the Excavation Extravaganza activity with your class, use the fossils they removed from their excavation site to do this activity. If you chose not to conduct the Excavation Extravaganza activity with your class, not to worry; you still can have your students do the Fossil Facelift.

Materials:

- Sand or Potting Soil
- 12 sturdy non-water soluble objects* (plan for one object for every two students)
- 12 trays
- Elmers glue
- Small paint brush
- Sheet of wax paper

***Note**—When you are choosing objects for this activity, keep in mind that fossils are usually very fragile. Think about using an object that requires your students to handle it carefully. Try using an egg.

1. Using the paint brush, coat the object with glue.
2. While the glue is wet, roll the object in the sand or soil until it is completely covered.
3. Place the object on the wax paper, and allow it to dry.
4. Once the objects are dry, place each one in a tray.
5. Now you are ready to start.

Suggestions:

1. If you did not do the Excavation Extravaganza activity with your class, please read through the Extension Activity, Introducing Observation and Hypothesis. It includes ideas about how to introduce your students to making observations and hypotheses. You will notice that before preparing the fossils students are asked to make observations and formulate an hypothesis.
2. If you have access to a video on fossil excavation and preparation, consider showing it. It will give students a visual image of scientists preparing fossils. A video probably will get them excited about doing the activity.
3. The directions are pretty simple, and students should be able to follow the procedure. You might take a few minutes to go over the activity with your students.

Fossil Facelift

Background:

Once Sue arrived at The Field Museum, the most difficult part of the excavation process, preparation of Sue's bones for study and display, got underway. When Sue's bones arrived at the Museum, they were still mostly covered by rocky material called matrix. Each bone had to be carefully removed from the matrix without being damaged.

Most of Sue's bones were taken to the McDonald's Fossil Preparation Laboratory located on the second floor of The Field Museum. Some of Sue's smaller bones were taken to another laboratory located in DinoLand U.S.A., part of Disney's Animal Kingdom at Walt Disney World Resort. Both of these "prep" labs are open to public viewing so people just like you who are visiting The Field Museum or Animal Kingdom can see how fossils are prepared.

Fossil preparators, people who are trained to clean fossils and get them ready for display and research, use a variety of tools and equipment to prepare and clean fossils. At first, preparators use an air scribe (a mini jackhammer) to remove chunks of rock from areas where there is no danger of damaging the bone. When they need to remove matrix closer to the actual bone, they use an air abrasive tool. This tool, which is very similar to the tool the dentist uses to dry your teeth, is a mini sandblaster that blows baking soda. This gentle abrasive removes dirt and other matrix from the fossils. While this equipment makes the preparation a bit easier, all of the delicate work is done by hand using equipment like dental scrapers, tiny brushes, and pins. Because fossils are often very delicate and brittle, they are then coated with a hardening liquid that soaks in and protects the fragile bone.



At The Field Museum Matthew Groves, a preparator, uses an air scribe to prepare Sue's skull.

© The Field Museum, Photo by John Weinstein, Neg#: GN89067_24c.

Fossil Facelift

Activity Description:

Students use a variety of tools to clean an object by removing matrix.

Materials:

- Matrix covered object
- Investigation Data Sheet
- Tiny brush
- Dental tools
- Toothpicks
- Magnifying glass

Procedure:

1. Working with a partner, gather the materials for this activity.
2. Before you start to remove matrix from your object, respond to #1–2 on the Investigation Data Sheet.
3. Using the hypothesis you developed, begin removing matrix from the object.
4. After you have completely removed the object from the matrix, respond to #3–6 on the Investigation Data Sheet.

4. Make and record new observations about the object now that the matrix is removed.

5. Describe two things that you discovered about your object that you did not know before you removed the matrix.

6. Would you consider a career as a fossil preparator? Why or why not?

How can Sue be in more than one place?

Background:

Sue's bones now are cleaned and prepared. What happens to them next? Scientists, excited to study and learn more about *T. rex* from the fossil, want to use the bones for scientific research. However, the public is excited to see Sue on display. Scientists and visitors alike who have followed the story of Sue since her discovery cannot wait to see and learn about the largest, most complete, and best preserved *T. rex* ever found. How can both groups get access to Sue at the same time?

To meet everyone's needs, the Museum decided to make casts, or replicas, of Sue's bones. That way there could be multiple Sues for multiple purposes. While the actual fossil and one cast will stay at The Field Museum to be accessible to scientists and Museum visitors, replicas are on the road as traveling exhibitions so that Sue is accessible to people nationwide.

Replicating fossils involves two steps - making the mold and then making the cast. The first step is to make a mold of the bone. A mold is an imprint, like a footprint you make when you walk barefoot in wet sand. The second step is to make a cast from this mold. A cast is a copy of the bone. For example, if you were to fill in your footprint with clay, you would be making a cast, or copy, of the bottom of your foot.

Specialists made molds and casts of all of the bones of Sue. To make the mold, preparators coated the entire bone with latex. Once the latex was dry, it was peeled carefully off the bone. This latex mold was then filled with polyester resin, a material that is very strong and durable once it has dried. This final product resulted in an exact model of a bone of Sue. These bones are now pieced together to make Sue stand again!

Activity Description:

Students are challenged to make a copy of an object that they can share with classmates. Using a variety of materials and techniques, students formulate and test different methods of replicating an object.

National Science Standards:

Content Standard A: Science as Inquiry

Abilities necessary to do scientific inquiry

- Design and conduct a scientific investigation
- Use appropriate tools and techniques to gather, analyze, and interpret data
- Develop descriptions, explanations, predictions, and models using evidence
- Think critically and logically to make the relationships between evidence and explanations

Understandings about scientific inquiry

Content Standard G: History and Nature of Science

Science as a human endeavor

Nature of science

Illinois State Standards:

English Language Arts

State Goal 1: Read with understanding and fluency.

- A. Apply word analysis and vocabulary skills to comprehend selections.
 - Late Elementary –2b
 - Middle School –3b
- C. Comprehend a broad range of reading materials.
 - Late Elementary –2a, 2f
 - Middle School –3a, 3f

State Goal 3: Write to communicate for a variety of purposes.

- C. Compose ideas in writing to accomplish a variety of purposes.
 - Late Elementary –2a
 - Middle School –3a

State Goal 4: Listen and speak effectively in a variety of situations.

- A. Listen effectively in formal and informal situations
 - Late Elementary –2b
 - Middle School –3b

Science

State Goal 11: Understand the process of scientific inquiry and technological designs to investigate questions, conduct experiments and solve problems.

- E. Know and apply the concepts, principles and processes of scientific inquiry.
 - Late Elementary –2a, 2b, 2d, 2e
 - Middle School –3a, 3c, 3f, 3g

State Goal 27: Understand the role of the arts in civilizations, past and present.

- A. Analyze how the arts function in history, society and everyday life.
 - Late Elementary –2a,
 - Middle School –3a
- B. Understand how the arts shape and reflect history, society and everyday life.
 - Late Elementary –2b
 - Middle School –3b

Objectives:

Concepts:

1. Students learn why fossils need to be copied.
2. Students learn how fossils are copied.

Skills:

1. Students make and record observations.
2. Students make an hypothesis, test that hypothesis, and then draw a conclusion.
3. Students make molds and casts.

Materials:

- Object
- Investigation Data Sheet
- Clay
- Plaster of paris
- Paper
- Markers

Procedure:

1. Make and record observations about your object on your Investigation Data Sheet, #1.
2. Brainstorm about how you can make a copy of your object from which others can study and learn. Record your ideas and hypothesis on your Investigation Data Sheet, #2.
3. Using materials supplied in class, test your ideas and hypothesis. Record your results on your Investigation Data Sheet, #3.
4. Using your results, come to a conclusion about the best method for replicating your object. Record your conclusion on your Investigation Data Sheet, #4.
5. Respond to #5 on your Investigation Data Sheet.

Preparation:

1. Make copies of the Investigation Data Sheet for each student.
2. Gather supplies for the activity. If your students did the Excavation Extravaganza activity, they can use one of their bones as the object. Otherwise, you might want to ask students to bring in their own object for this activity.

Suggestions:

1. If you have a video covering molding and casting, consider showing it before doing this activity. It will give students a visual image of the processes of molding and casting.
2. Have students work in small groups of 3–4 people. Each person is responsible for making a copy of his or her object, but working in groups allows students to brainstorm and get feedback from others.
3. Observation and hypothesis are important concepts in this activity. If you want to review these terms with your students, refer to the Extension Activity, Introducing Observation and Hypothesis. This extension activity is located in the Excavation Extravaganza Teacher Pages.

How can Sue be in more than one place?

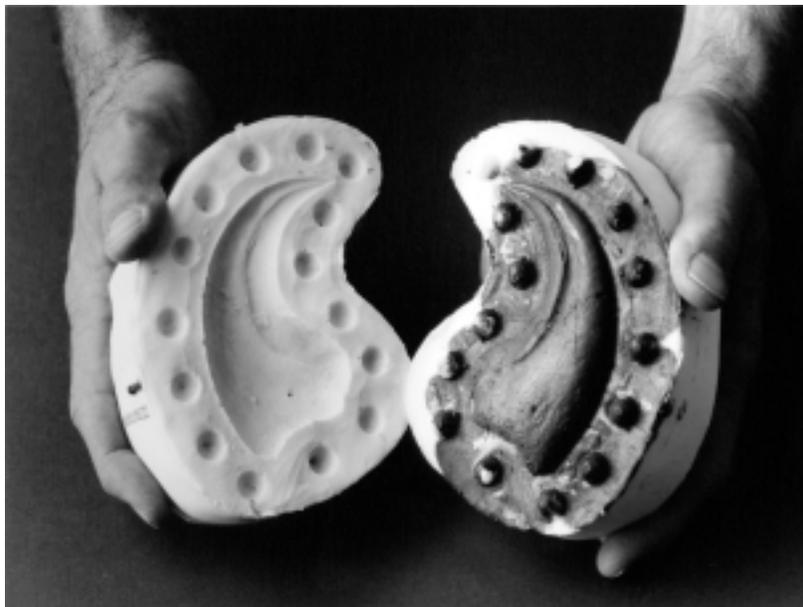
Background:

Sue's bones now are cleaned and prepared. What happens to them next? Scientists, excited to study and learn more about *T. rex* from the fossil, want to use the bones for scientific research. However, the public is excited to see Sue on display. Scientists and visitors alike who have followed the story of Sue since her discovery cannot wait to see and learn about the largest, most complete, and best preserved *T. rex* ever found. How can both groups get access to Sue at the same time?

To meet everyone's needs, the Museum decided to make casts, or replicas, of Sue's bones. That way there could be multiple Sues for multiple purposes. While the actual fossil and one cast will stay at the Museum to be accessible to scientists and Museum visitors, replicas are on the road as traveling exhibitions so that Sue is accessible to people nationwide.

Replicating fossils involves two steps—making the mold and then making the cast. The first step is to make a mold of the bone. A mold is an imprint, like a footprint you make when you walk barefoot in wet sand. The second step is to make a cast from this mold. A cast is a copy of the bone. For example, if you were to fill in your footprint with clay, you would be making a cast, or copy, of the bottom of your foot.

Specialists made molds and casts of all of the bones of Sue. To make the mold, preparators coated the entire bone with latex. Once the latex was dry, it was peeled carefully off the bone. This latex mold was then filled with polyester resin, a material that is very strong and durable once it has dried. This final product resulted in an exact model of a bone of Sue. These bones are now pieced together to make Sue stand again!



A mold and cast of an undetermined carnivorous dinosaur claw found at the Sue excavation site.

© The Field Museum, Photo by John Weinstein, Neg#: GEO 86147_53c.

How can Sue be in more than one place?

Activity Description:

Students are challenged to make a copy of an object that they can share with classmates. Using a variety of materials and techniques, students formulate and test different methods of replicating an object.

Materials:

- Object
- Investigation Data Sheet
- Clay
- Plaster of Paris
- Paper
- Markers

Procedure:

1. Make and record observations about your object on your Investigation Data Sheet, #1.
2. Brainstorm about how you can make a copy of your object from which others can study and learn. Record your ideas and hypothesis on your Investigation Data Sheet, #2.
3. Using materials supplied in class, test your ideas and hypothesis. Record your results on your Investigation Data Sheet, #3.
4. Using your results, come to a conclusion about the best method for replicating your object. Record your conclusion on your Investigation Data Sheet, #4.
5. Respond to #5 on your Investigation Data Sheet.

4. Based on the results of your tests, what is the best method to use to replicate your object?
Explain your conclusion in detail.

5. Would you consider a career as a fossil preparator? Why or why not?

Research

What are observation, theory, and speculation?

Background:

Fossils are a key to understanding the past. They tell the story of species, like *Tyrannosaurus rex*, which no longer walk the earth. What can we learn from Sue? Unlike many *T. rex* specimens, which have many missing or damaged bones, Sue is 90% complete. Due to remarkable preservation, it is still possible to see fine surface details showing where muscles, tendons, and other soft tissues attached to the bone. Sue's high quality provides scientists with information that, ultimately, will significantly enhance our understanding of *Tyrannosaurus rex*.

Activity Description:

Students use ongoing scientific research about Sue to understand the differences among observation, theory, and speculation.

National Science Standards:

Content Standard A: Science as Inquiry

Abilities necessary to do scientific inquiry

- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.
- Think critically and logically to make the relationships between evidence and explanations.
- Recognize and analyze alternative explanations and predictions.

Content Standard C: Life Science

Diversity and adaptations of organisms

Content Standard D: Earth and Space Science

Earth's history

Content Standard G: History and Nature of Science

Science as a human endeavor

Nature of science

Illinois State Standards:

English Language Arts

State Goal 1: Read with understanding and fluency.

A. Apply word analysis and vocabulary skills to comprehend selections.

- Late Elementary –2b
- Middle School –3b

C. Comprehend a broad range of reading materials.

- Late Elementary –2a, 2f
- Middle School –3a, 3f

State Goal 3: Write to communicate for a variety of purposes

C. Compose ideas in writing to accomplish a variety of purposes.

- Late Elementary –2a
- Middle School –3a

State Goal 4: Listen and speak effectively in a variety of situations.

A. Listen effectively in formal and informal situations

- Late Elementary -2b
- Middle School -3b

Science

State Goal 11: Understand the process of scientific inquiry and technological designs to investigate questions, conduct experiments and solve problems.

F. Know and apply the concepts, principles and processes of scientific inquiry.

- Late Elementary -2a, 2b, 2d, 2e
- Middle School -3a, 3c, 3f, 3g

State Goal 12: Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences.

A. Know and apply concepts that explain how living things function, adapt and change.

- Middle School -3c

B. Know and apply concepts that describe how living things interact with each other and with their environment.

- Late Elementary -2b,
- Middle School -3b

E. Know and apply concepts that describe the features and processes of the Earth and its resources.

- Late Elementary -2b
- Middle School -3b

State Goal 13: Understand the relationships among science technology and society in historical and contemporary contexts.

B. Know and apply concepts that describe the interaction between science, technology and society.

- Late Elementary -2a, 2b,2c
- Middle School -3a, 3b, 3c

Objectives:

Concepts:

1. Students will learn about ongoing Sue research, such as the relationship between *Tyrannosaurus rex* and birds.
2. Students will learn about observation, theory, and speculation.

Skills:

1. Students will evaluate statements about Sue to understand the differences among observation, theory, and speculation.
2. Students will conduct research on their own "fossil" and produce statements of observation, theory, and speculation.

Materials

- Investigation Data Sheet

Procedure:

1. Respond to #1–8 on your Investigation Data Sheet.

What are observation, theory, and speculation?

Background:

Fossils are a key to understanding the past. They tell the story of species, like *Tyrannosaurus rex*, which no longer walk the earth. What can we learn from Sue? Unlike many *T. rex* specimens, which have many missing or damaged bones, Sue is 90% complete. Due to remarkable preservation, it is still possible to see fine surface details showing where muscles, tendons, and other soft tissues attached to the bone. Sue's high quality provides scientists with information that, ultimately, will significantly enhance our understanding of *Tyrannosaurus rex*.

Activity Description:

Students use ongoing scientific research about Sue to understand the differences among observation, theory, and speculation.



© The Field Museum, Photo by John Weinstein, Neg#: GEO 86284

Materials

- Investigation Data Sheet

Procedure:

1. Respond to #1–8 on your Investigation Data Sheet.

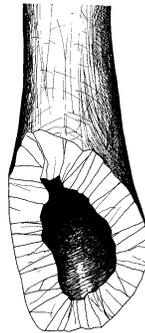
What are observation, theory, and speculation?

Investigation Data Sheet

What is an observation?

An *observation* is information collected using your five senses. You can show observations to others. For example, scientists have *observed* that *Tyrannosaurus rex* had hollow bones.

See for yourself.



Cross-section of Sue's tibia showing that the bone is thin-walled and hollow.

1. After examining the photo of Sue's skull on page 57, make three *observations*.

a.

b.

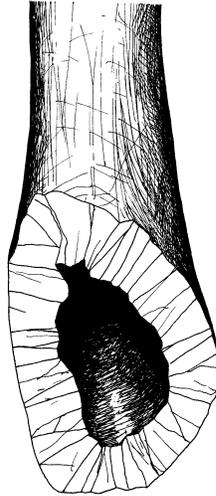
c.

Sue's skull.

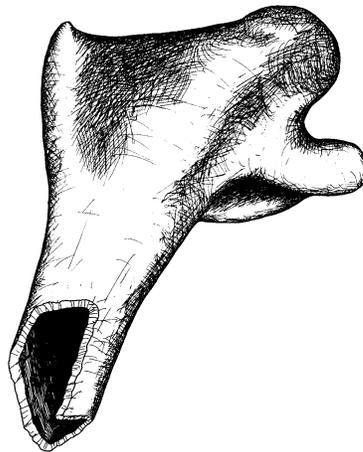
What is a theory?

A *theory* is an explanation of data based on observations. Theories are testable. For example, some scientists *theorize* that *Tyrannosaurus rex* and other meat-eating dinosaurs are closely related to birds. Why do some scientists believe birds evolved from dinosaurs? They base their *theory* on the following *observations*. See for yourself.

Observation: Both birds and *T. rex* have hollow and thin-walled bones.

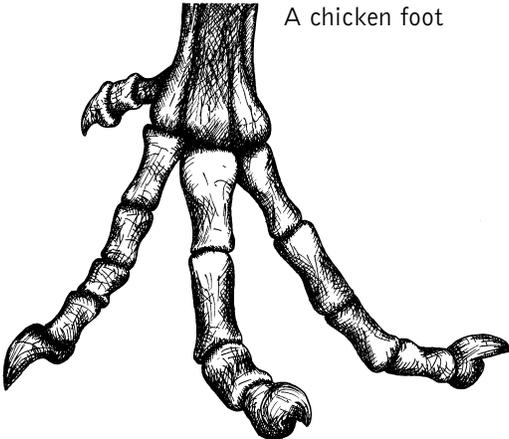
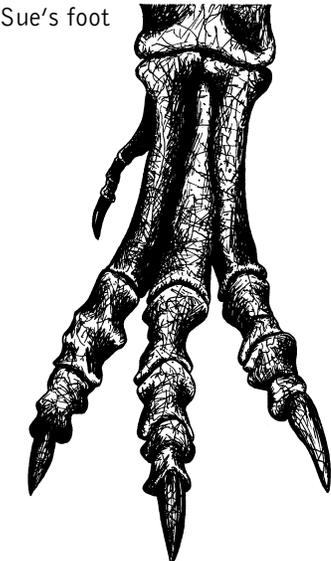


Cross-section of Sue's tibia showing that the bone is thin-walled and hollow.

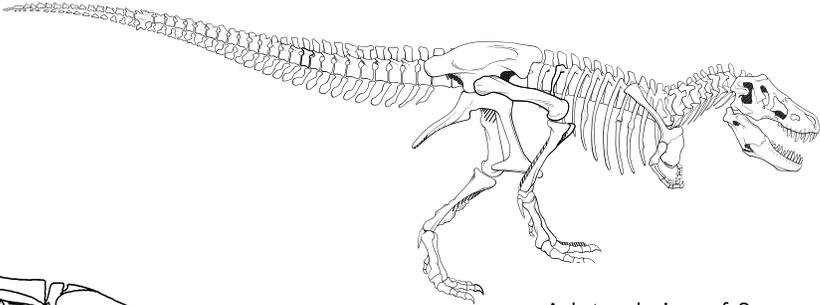
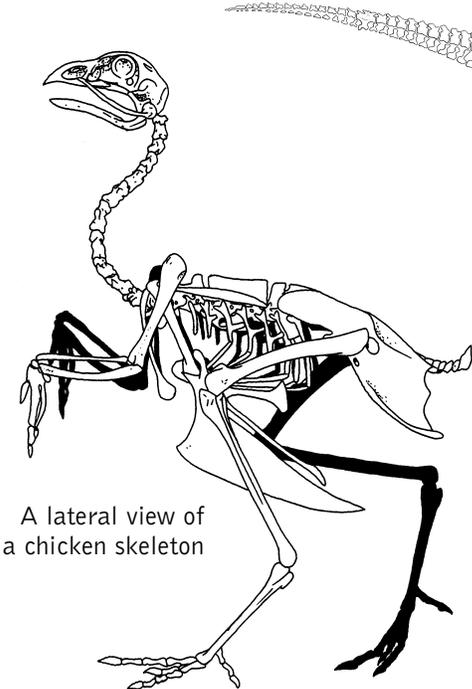


Cross-section of a pigeon humerus showing that the bone is thin-walled and hollow.

Observation: Both birds and *T. rex* have three forward pointing toes.



Observation: Both birds and theropods (lizard-hipped, meat-eating dinosaurs) have skeletal structures indicating that they walked on the two hind limbs.



4. We still have many questions about *T. rex* such as the following: Was it a predator or scavenger? What did it sound like? How did it stand, move, eat, and live? Many of these questions are still unresolved because fossils have not provided information scientists can use to develop a *theory*. Use your imagination to *speculate* about Sue. (You can either make a drawing or write a description.)

5. Now that you have made *observations*, developed a *theory*, and *speculated* about Sue, do the same for your own object. Examine your object, and make three *observations*.

a.

b.

c.

6. Based on your *observations* of your object, develop a *theory* about it.

7. Explain how your *observations* support your *theory*.

8. Use your imagination to *speculate* about your object. (You can either make a drawing or write a description.)

Tyrannosaurus Theories

Background:

What does Sue have in common with a crocodile and a chicken? Scientists believe that dinosaurs, birds, and crocodiles evolved from the same group of reptiles. By **observing** and studying bones of all three, scientists have **theorized** that all three share a common ancestor. Common ancestry means that while *Tyrannosaurus rex*, crocodiles, and chickens are different species, they share features because they are closely related evolutionarily. This link allows scientists to formulate theories that address questions unanswered by fossil remains. For example, while sedimentary rock, like sandstone, is excellent at preserving bone, it cannot document behaviors like what sounds a *T. rex* made or how it interacted with other dinosaurs. However, by **observing** the characteristics and behavior of birds and crocodiles, dinosaurs' closest modern relatives, scientists can formulate **theories** about how *T. rex* lived and behaved.

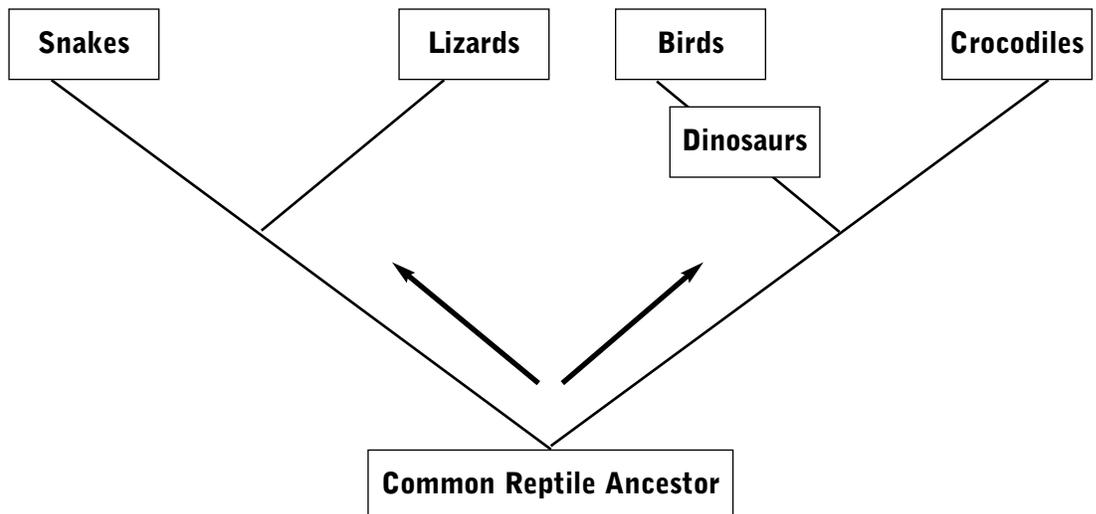


Diagram: Phylogeny of birds, dinosaurs, and different groups of modern reptiles

Activity Description:

There are many unanswered questions about Sue because no direct evidence is preserved in the fossil record. Students research crocodiles and birds, which share a common ancestor with *Tyrannosaurus rex*, to formulate theories that address these questions.

National Science Standards:**Content Standard A: Science as Inquiry**

Abilities necessary to do scientific inquiry

- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.
- Think critically and logically to make the relationships between evidence and explanations.
- Recognize and analyze alternative explanations and predictions.

Content Standard C: Life Science

Diversity and adaptations of organisms

Content Standard D: Earth and Space Science

Earth's history

Content Standard G: History and Nature of Science

Science as a human endeavor

Nature of science

Illinois State Standards:**English Language Arts****State Goal 1: Read with understanding and fluency.**

A. Apply word analysis and vocabulary skills to comprehend selections.

- Late Elementary –2b
- Middle School –3b

C. Comprehend a broad range of reading materials.

- Late Elementary –2a, 2f
- Middle School –3a, 3f

State Goal 3: Write to communicate for a variety of purposes.

C. Compose ideas in writing to accomplish a variety of purposes.

- Late Elementary –2a
- Middle School –3a

State Goal 4: Listen and speak effectively in a variety of situations.

A. Listen effectively in formal and informal situations

- Late Elementary –2b
- Middle School –3b

State Goal 5: Use the language arts to acquire, assess and communicate information.

A. Locate, organize and use information from various sources to answer questions, solve problems and communicate ideas.

- Late Elementary –2a, 2b
- Middle School –3a, 3b

B. Analyze and evaluate information acquired from various sources.

- Late Elementary –2a, 2b
- Middle School –3a, 3b

Mathematics

State Goal 10: *Collect, organize and analyze data using statistical methods; predict results; and interpret uncertainty using concepts of probability.*

A. Organize, describe and make predictions from existing data.

- Late Elementary –2c
- Middle School –3c

C. Determine, describe and apply the probabilities of events.

- Late Elementary –2b
- Middle School –3b

Science

State Goal 11: *Understand the process of scientific inquiry and technological designs to investigate questions, conduct experiments and solve problems.*

A. Know and apply the concepts, principles and processes of scientific inquiry.

- Late Elementary –2a, 2b, 2d, 2e
- Middle School –3a, 3c, 3f, 3g

State Goal 12: *Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences.*

A. Know and apply concepts that explain how living things function, adapt and change.

- Middle School –3c

Objectives:

Concepts:

1. Students learn that organisms with shared common ancestry often share features.
2. Students learn how to formulate a theory from observations.

Skills:

1. Students formulate theories.
2. Students conduct research.

Materials:

- Investigation Data Sheet
- Resource materials

Procedure:

1. Read and follow the instructions on the Investigation Data Sheet.
2. Working with a partner, conduct research.
3. Record your findings on the Investigation Data Sheet.
4. Share your theory with your classmates.

Preparation:

1. Research is a major component of this activity. Plan on providing your students with a variety of resources. Consider talking to your school's librarian before you use this activity. He/she probably can suggest a number of titles for your students to use as they are researching their questions. Think about scheduling ½–1 hour of class time in the library.
2. Make copies of the Background and Investigation Data Sheet for each student.

Suggestions:

1. Go over the instructions on the Investigation Data Sheet with your students before asking them to start their research. It is important that your students understand the instructions so consider selecting one of the questions to research as a class.
2. This activity provides your students with an opportunity to either learn about or practice citing sources. Go over the format for recording bibliographic information with your students. If you are interested in reviewing the MLA Bibliographic Citation Guide, go to

<http://www.sccd.ctc.edu/~library/mlacite.html>

Investigation Data Sheet Answers:

| Questions | Chicken | Crocodiles | Sue Theory |
|--|---------|------------|------------------------|
| Does this animal nurse her young? | No | No | Probably Not |
| Does this animal build a nest for her young? | Yes | Yes | Probably |
| Was this animal warm blooded? | Yes | No | Not Enough Information |
| Does this animal lay eggs? | Yes | Yes | Probably |
| Does this animal give birth to live young? | No | No | Probably Not |
| Does this animal have feathers? | Yes | No | Not Enough Information |
| Does this animal have fur? | No | No | Probably Not |
| Does this animal have a poisonous bite? | No | No | Probably Not |

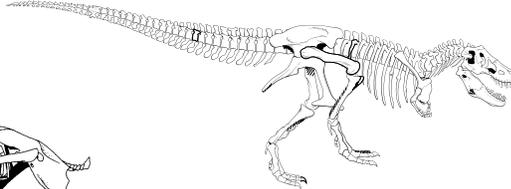
Tyrannosaurus Theories

Background:

What does Sue have in common with a crocodile and a chicken?



A lateral view of a chicken



A lateral view of Sue



A lateral view of a crocodile

Scientists believe that dinosaurs, birds, and crocodiles evolved from the same group of reptiles. By **observing** and studying bones of all three, scientists have **theorized** that all three share a common ancestor. Common ancestry means that while *Tyrannosaurus rex*, crocodiles, and chickens are different species, they share features because they are closely related evolutionarily. This link allows scientists to formulate theories that address questions unanswered by fossil remains. For example, while sedimentary rock, like sandstone, is excellent at preserving bone, it cannot document behaviors like what sounds a *T. rex* made or how it interacted with other dinosaurs. However, by observing the characteristics and behavior of birds and crocodiles, dinosaurs' closest modern relatives, scientists can formulate **theories** about how *T. rex* lived and behaved.

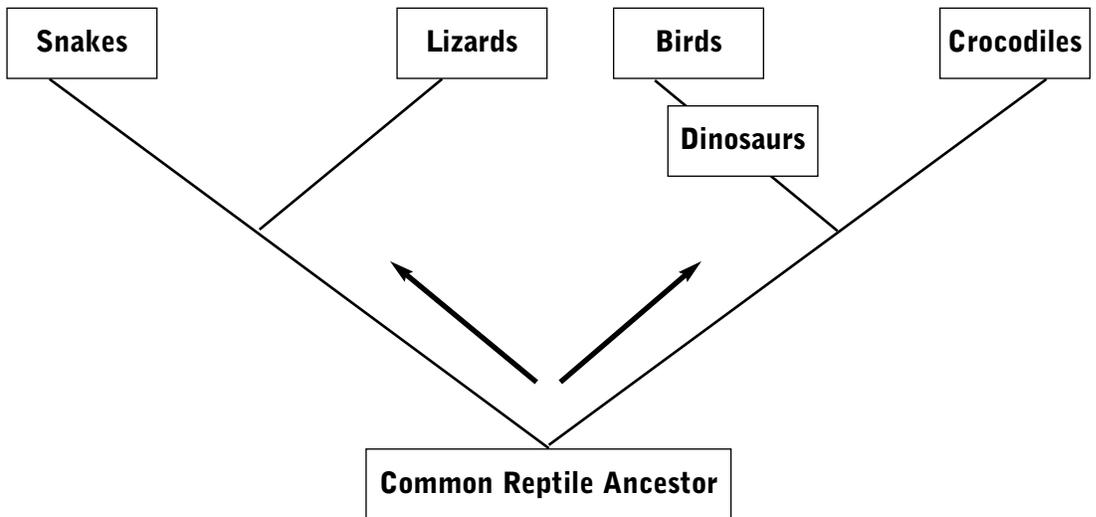


Diagram: Phylogeny of birds, dinosaurs, and different groups of modern reptiles

Activity Description:

There are many unanswered questions about Sue because no direct evidence is preserved in the fossil record. Students research crocodiles and birds, which share a common ancestor with *Tyrannosaurus rex*, to formulate theories that address these questions.

Materials:

- Investigation Data Sheet
- Resource materials

Procedure:

1. Read and follow the instructions on the Investigation Data Sheet.
2. Working with a partner, conduct research.
3. Record your findings on the Investigation Data Sheet.
4. Share your theory with your classmates.

Tyrannosaurus Theories

Investigation Data Sheet

Using the theory that birds and crocodiles are dinosaurs' closest modern relatives, scientists are able to use observations of these animals to formulate theories about *T. rex*. Use this technique to formulate your own theories about the following questions:

Did Sue nurse her young?

Did Sue build a nest for her young?

Was Sue warm-blooded?

Did Sue lay eggs?

Did Sue give birth to live young?

Did Sue have feathers?

Did Sue have fur?

Did Sue have a poisonous bite?

Instructions:

1. Choose one of the questions from the list. For example, did Sue nurse her young? Ask the same question of two of *T. rex*'s closest living relatives, a chicken and a crocodile. Does a chicken nurse her young? Does a crocodile nurse her young?
2. Conduct research to answer these questions. For example, after doing some research you would learn that neither chickens nor crocodiles nurse their young.
3. If the answer is no for both a crocodile and a chicken, then the answer is probably no for Sue as well. You have enough information to make a theory. Did Sue nurse her young? Probably not!
4. If the answer is yes for both a crocodile and a chicken, then the answer is probably yes for Sue as well. Again, you have enough information to make a theory.
5. If the answer is yes for one and no for the other, then guess what? You do not have enough information to make a theory.

Ready to give theorizing a try?

1. Which question did you select from the list? (Example: Did Sue build a nest for her young?)

2. What questions are you researching? (Example: Does a chicken build a nest for her young? Does a crocodile build a nest for her young?)

Ready, set, research.

3. What did you learn?

4. What was your source of information? Record bibliographical information.

5. Use your research to formulate a theory.

6. What fossil evidence would support your theory?

7. What are the differences between your bone and the same type of bone in a *T. rex*?

Anatomy 101

Background:

As Field Museum staff were preparing and researching Sue, they identified which of the approximately 250 different bones that make up a *Tyrannosaurus rex* were present and which were missing. Sue is an exciting fossil because not only is she the largest but she also is the most complete and best preserved *T. rex* ever found. Having most of the bones from one specimen means that scientists have access to new information about this extinct species. Each bone is important because it tells a different part of Sue's story, which may lead scientists to a better understanding of *T. rex*.

For example, Sue's right arm may provide new information about *T. rex*. It is only the second *T. rex* arm ever found, and it could provide clues about the strength and motion of the forelimbs. Scientist will continue to learn more about the forelimbs by analyzing the size and shape of each bone.

Activity Description:

Using Sue's Anatomy Guide that provides information about the major bones found in *Tyrannosaurus rex*, students identify what kind of bones (i.e. vertebrae, pelvis, femur, etc.) they excavated during the Excavation Extravaganza activity. In addition to identifying bones, students research similarities and differences between the bones they discovered and Sue's bones.

National Science Standards:

Content Standard A: Science as Inquiry

Abilities necessary to do scientific inquiry

- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.
- Think critically and logically to make the relationships between evidence and explanations.
- Recognize and analyze alternative explanations and predictions.

Content Standard C: Life Science

Diversity and adaptations of organisms

Content Standard D: Earth and Space Science

Earth's history

Content Standard G: History and Nature of Science

Science as a human endeavor

Nature of science

Illinois State Standards:

English Language Arts

State Goal 1: Read with understanding and fluency.

- A. Apply word analysis and vocabulary skills to comprehend selections.
- Late Elementary –2b
 - Middle School –3b

C. Comprehend a broad range of reading materials.

- Late Elementary –2a, 2f
- Middle School –3a, 3f

State Goal 3: Write to communicate for a variety of purposes.

C. Compose ideas in writing to accomplish a variety of purposes.

- Late Elementary –2a
- Middle School –3a

State Goal 4: Listen and speak effectively in a variety of situations.

A. Listen effectively in formal and informal situations

- Late Elementary –2b
- Middle School –3b

Science

State Goal 11: Understand the process of scientific inquiry and technological designs to investigate questions, conduct experiments and solve problems.

A. Know and apply the concepts, principles and processes of scientific inquiry.

- Late Elementary –2a, 2b, 2d, 2e
- Middle School –3a, 3c, 3f, 3g

State Goal 12: Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences.

A. Organize, describe and make predictions from existing data.

- Late Elementary –2c

Objectives:

Concepts:

1. Students learn about *T. rex*'s basic anatomy.

Skills:

1. Students make and record observations and hypothesis.
2. Students research their fossil find.

Materials:

- Bones from Excavation Extravaganza
- Bone Sheet from Excavation Extravaganza
- Sue's Anatomy Guide
- Glue

Procedures:

1. Read Sue's Anatomy Guide.
2. Compare your observations about the bones that you collected during Excavation Extravaganza with the bones in Sue's Anatomy Guide.
3. Formulate hypotheses about the kind of bones that you uncovered. Record your hypotheses on your Investigation Data Sheet.
4. Share your hypotheses with the class.

Preparation:

1. Make copies of the Background, Sue's Anatomy Guide, and Investigation Data Sheet for each student. Please note that students will need one Investigation Data Sheet for each kind of bone they identify. Plan on making 4 Investigation Data Sheets per student.
2. Make sure students have access to their bones and Bone Sheet from the Excavation Extravaganza activity.

Suggestions:

1. Students should work with their Excavation Extravaganza team on this activity. Using teams insures that students are working with the bones that they excavated.
2. Explain to students that they should start a new Investigation Data Sheet for each different kind of bone they identify. If they find more than one bone of a particular type (for example three chest vertebrae) they should record the specimen number of each bone on one Investigation Data Sheet.
3. Keep in mind that some of the bones that students excavated are broken. Encourage students with broken bones to talk with other teams. Perhaps another group has the missing section of their broken bone. Have students who successfully reunite pieces of broken bone glue the pieces back together. It might be fun to have your class keep track of where in the excavation site each piece of the broken bone was discovered.
4. Because each team will have only a few bones, it is important for your students to share what kinds of bones they found with the entire class. Have your class create a bone inventory on the board. Use this inventory to generate a class discussion about whether or not the bones belong to one individual. Ask students to brainstorm about the kind of bones, like skull or foot bones, they did not find during the excavation.

Extension Activity: Fossil Exhibition

Have your students work together to unveil their fossil in an exhibition. After preparing and researching their fossil, they will be ready to share their hard work with others. They can finish getting their fossil ready for public viewing by designing the layout of their exhibition, mounting their fossil, writing the label copy summarizing their research, and making illustrations and drawings to bring their fossil to life.

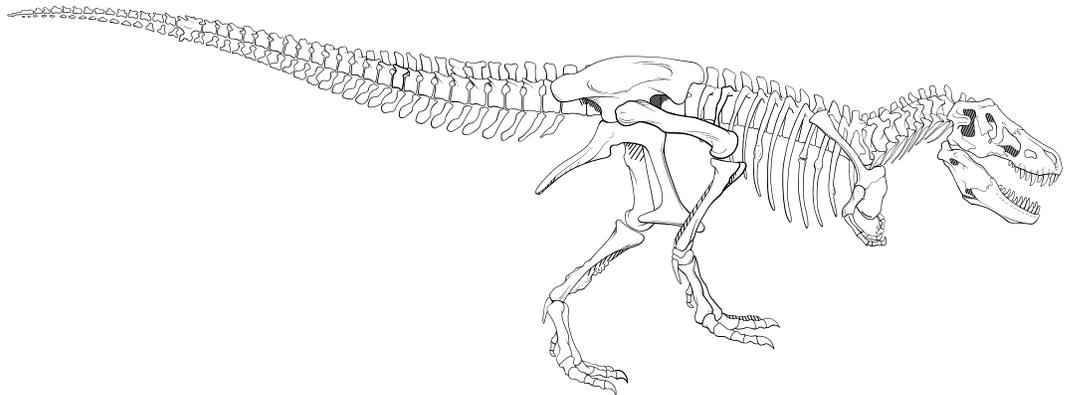
Students need class time to work with each other and make decisions about how they want to proceed with the exhibition. Work should be divided so that everyone has something substantial to work on, preferably in an area of exhibition production that interests him/her. Ideally, the culmination of this activity involves sharing the completed exhibition with an audience, perhaps with another class or as a temporary display in a library or other public location in the school.

Anatomy 101

Background:

As Field Museum staff were preparing and researching Sue, they identified which of the approximately 250 different bones that make up a *Tyrannosaurus rex* were present and which were missing. Sue is an exciting fossil because not only is she the largest but she also is the most complete, and best preserved *T. rex* ever found. Having most of the bones from one specimen means that scientists have access to new information about this extinct species. Each bone is important because it tells a different part of Sue's story, which may lead scientists to a better understanding of *T. rex*.

For example, Sue's right arm may provide new information about *T. rex*. It is only the second *T. rex* arm ever found, and it could provide clues about the strength and motion of the forelimbs. Scientists will continue to learn more about the forelimbs by analyzing the size and shape of each bone.



Activity Description:

Using Sue's Anatomy Guide that provides information about the major bones found in *Tyrannosaurus rex*, students identify what kind of bones (i.e. vertebrae, pelvis, femur, etc.) they excavated during the Excavation Extravaganza activity. In addition to identifying bones, students research similarities and differences between the bones they discovered and Sue's bones.

Materials:

- Bones from Excavation Extravaganza
- Bone Sheet from Excavation Extravaganza
- Sue's Anatomy Guide
- Glue

Procedures:

1. Read Sue's Anatomy Guide.
2. Compare your observations about the bones that you collected during Excavation Extravaganza with the bones in Sue's Anatomy Guide.
3. Formulate hypotheses about the kind of bones that you uncovered. Record your hypotheses on your Investigation Data Sheet.
4. Share your hypothesis with the class.

Anatomy 101

Sue's Anatomy Guide

Use this guide, which provides information about major bones found in a *Tyrannosaurus rex*, to identify bones you found during the Excavation Extravaganza activity.

Vertebrae (back bones)

There are three different types of bones that make up the vertebral column: neck, chest and tail. Generally, vertebrae increase in size from the head to the hips and decrease in size from the hip to the tip of the tail.

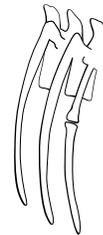
Neck

Small, sharp, and spiny ribs characterize these narrow vertebrae.



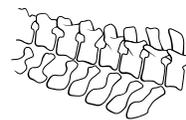
Chest

These vertebrae are typically larger than neck vertebrae. The chest vertebrae have larger ribs extending from the middle.



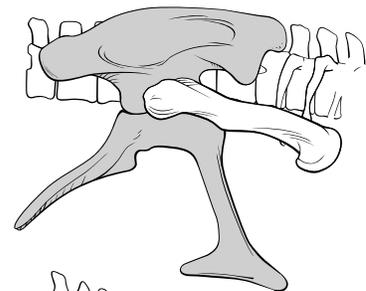
Tail

These vertebrae are typically longer than neck vertebrae. The process on top is rectangular in shape. Each tail vertebra has a chevron below it, which looks like a small, flat rib.



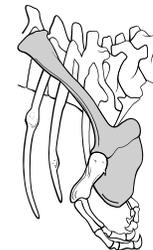
Pelvis (hip bones)

The pelvis is composed of three large bones. When these bones are articulated, they meet at a central point, the hip socket. The ilium (the largest, flattest bone) sits along the vertebrae of the *T. rex*.



Pectoral Girdle (shoulder blade and associated bones)

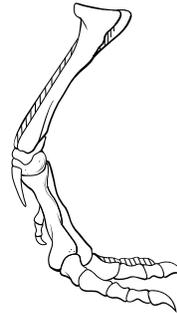
The pectoral girdle is a long, thin bone that sits on the rib cage. One end of the bone is expanded and significantly larger than the other end. This end of the bone includes the socket for the humerus.



Femur (thigh bone)
The largest limb bone in the body.



Tibia & Fibula (lower leg bones)
These two bones are the same length, almost as long as the femur.



Humerus (upper arm bone)
A small, long, and fairly thin bone that fits with the shoulder blade.



Ulna & Radius (forearm bones)
These two bones of the forearm are about the same size and length.



Exhibition

Sue in the Flesh: A portrait of fact, theory, and speculation

Background:

Sue was unveiled at The Field Museum on May 17, 2000. Her skeleton awes visitors as they enter Stanley Field Hall. However, Sue is more than a collection of bones. Sue tells an amazing story, which the Museum shares with the public by presenting factual information, theories resulting from scientific research, and speculation about what Sue looked like when she lived. The Sue exhibition represents over two years of work by scientists, preparators, exhibit designers, illustrators, educators, and engineers to capture visitors' attention by bringing Sue to life in their imagination.

Activity Description:

Using factual information about Sue and theories that scientists are currently researching, students speculate about what Sue looked like when she lived during the Late Cretaceous.

National Science Standards:

Content Standard A: Science as Inquiry

Abilities necessary to do scientific inquiry

- Develop descriptions, explanations, predictions, and models using evidence
- Think critically and logically to make the relationships between evidence and explanations
- Recognize and analyze alternative explanations and predictions

Content Standard G: History and Nature of Science

Nature of science

Illinois State Standards:

English Language Arts

State Goal 1: Read with understanding and fluency.

A. Apply word analysis and vocabulary skills to comprehend selections.

- Late Elementary –2b
- Middle School –3b

C. Comprehend a broad range of reading materials.

- Late Elementary –2a, 2f
- Middle School –3a, 3f

State Goal 3: Write to communicate for a variety of purposes.

C. Compose ideas in writing to accomplish a variety of purposes.

- Late Elementary –2a
- Middle School –3a

State Goal 4: Listen and speak effectively in a variety of situations.

A. Listen effectively in formal and informal situations

- Late Elementary –2b
- Middle School –3b

Science

State Goal 11: *Understand the process of scientific inquiry and technological designs to investigate questions, conduct experiments and solve problems.*

A. Know and apply the concepts, principles and processes of scientific inquiry.

- Late Elementary –2a, 2b, 2d, 2e
- Middle School –3a, 3c, 3f, 3g

State Goal 13: *Understand the relationships among science technology and society in historical and contemporary contexts.*

A. Know and apply the accepted practices of science

- Late Elementary –2b
- Middle School –3b

Fine Arts

State Goal 27: *Understand the role of the arts in civilizations, past and present.*

A. Analyze how the arts function in history, society and everyday life.

- Late Elementary –2a,
- Middle School –3a

B. Understand how the arts shape and reflect history, society and everyday life.

- Late Elementary –2b
- Middle School –3b

Objectives:**Concept:**

1. Students will learn about ongoing Sue research such as vital statistics, sense of smell, and eating habits.
2. Students will learn about observation, theory, and speculation.

Skills:

1. Students will evaluate and apply observation, theory, and speculation to their drawing of Sue.

Materials:

- Art and craft supplies
- Sue Information Data Sheet
- Lateral view of Sue's skeleton
- Investigation Data Sheet

Procedure:

1. Read the Sue Information Data Sheet.
2. Using the Sue Information Data Sheet and your imagination, create a drawing or 3-D model of Sue.
3. Respond to #1–4 on your Investigation Data Sheet.

Preparation:

1. Make copies of the Background and Investigation Data Sheet for each student.
2. Gather arts and craft supplies for this activity.

Suggestions

1. Go over the Sue Information Data Sheet with your students. Use the facts, theories, and unanswered questions from the data sheet to spark a discussion with your students. Ask your students what unanswered questions they still have about Sue. Your students can use their artwork to speculate and answer their questions about Sue.
2. Have your students share their artwork with the class. If you have time, ask your students to compare their artwork with each other to note the similarities and differences.
3. Use student artwork to decorate the classroom.

Sue in the Flesh: A portrait of fact, theory, and speculation

Background:

Sue was unveiled at The Field Museum on May 17, 2000. Her skeleton awes visitors as they enter Stanley Field Hall. However, Sue is more than a collection of bones. Sue tells an amazing story, which the Museum shares with the public by presenting factual information, theories resulting from scientific research, and speculation about what Sue looked like when she lived. The Sue exhibition represents over two years of work by scientists, preparators, exhibit designers, illustrators, educators, and engineers to capture visitors' attention by bringing Sue to life in their imagination.



Activity Description:

Using factual information about Sue and theories that scientists are currently researching, students speculate about what Sue looked like when she lived during the Late Cretaceous.

Materials:

- Art and craft supplies
- Sue Information Data Sheet
- Lateral view of Sue's skeleton
- Investigation Data Sheet

Procedure:

1. Read the Sue Information Data Sheet.
2. Using the Sue Information Data Sheet and your imagination, create a drawing or 3-D model of Sue.
3. Respond to questions #1–4 on your Investigation Data Sheet.

Sue in the Flesh

Sue Information Data Sheet

Use what you know and what you want to know to *speculate* about what Sue looked and acted like when she was alive. Create a drawing or 3-D model of Sue that captures your vision of Sue.

Facts

Facts are things we know because we can see them and show them to others. Use these facts about Sue to help you imagine what she looked like when she was alive.

SCIENTIFIC NAME: *Tyrannosaurus rex* (From the Greek and Latin for “tyrant lizard king”)

TIME: Late Cretaceous Period, 67–65 million years ago

RANGE: Western North America

SIZE: 42 feet (12.9 meters) long, 13 feet (4.0 meters) high at the hips

WEIGHT: about 7 tons (6.4 metric tons)

LENGTH OF SKULL: 5.2 feet (1.6 meters)

SIZE OF BRAIN CAVITY: just big enough to hold a quart of milk

NUMBER OF TEETH: 58

LENGTH OF TEETH: 7.5 to 12 inches (19 to 30.5 cm)

- It took six fossil hunters 17 days to get Sue out of the ground; it took ten preparators two years to clean and repair her bones.
- It took a team of seven preparators over 3,500 hours to clean and repair Sue’s skull.
- The shape and location of Sue’s eye sockets indicate that her eyes faced forward.
- CT scans of Sue’s braincase show that the brain was about a foot long (30.5 cm) and shaped like a knobby sweet potato.
- Sue’s stapes, the slender rod that connects the eardrum to the inner ear, is one of the smallest bones in her skeleton. Bones this tiny and fragile almost never become fossilized. In fact, Sue’s stapes is the first one ever discovered in a *T. rex*.

- A *T. rex* skeleton is made up of more than 250 bones. Sue was found with most of those bones. She is missing only a foot, an arm, and a few ribs and vertebrae.
- Only two complete *T. rex* forelimbs have ever been found. Sue's is one of them.
- Sue is the largest, most complete, and best preserved *T. rex* ever found. Her skeleton is 90% complete. Sue's legs are enormous, but her arms are the size of a human's. They are so short they could not even reach her mouth. No one knows how *T. rex* used these tiny forelimbs.
- Sue's razor-sharp teeth were continually shed and re-grown during her lifetime.
- By x-raying Sue's ribs, it was determined that some of them had been broken and healed.
- Sue's tail is 20-feet long. It has 35 of the 47 vertebrae that make up a *T. rex* tail, which makes it the most complete *T. rex* tail ever found.

Theories

Theories are possible explanations based on observations. Use these theories about Sue to help you imagine what she looked like or how she behaved when she was alive.

Observation: Sue's olfactory bulbs, the region in the brain that detects smell, are about the same size as the rest of the brain. **Theory:** This observation leads scientists to believe that Sue had a powerful sense of smell. Sue may have followed her nose to locate a meal long before she could see it.

Observation: Sue's teeth have sharp points and are serrated. **Theory:** This observation suggests to scientists that Sue was carnivorous because her teeth were perfect for tearing and slicing the flesh of other dinosaurs. She probably tore off chunks of meat and swallowed them whole.

Observation: As animals grow old, their bones undergo changes: some wear down, others fuse together, and still others develop bony calluses. Many of the bones in Sue's skeleton show signs of old age. **Theory:** This observation suggests to scientists that Sue was an old *T. rex*.

Observation: Bird skeletons share many features with those of meat-eating dinosaurs like Sue. Sue's skeleton provided a key piece of the puzzle that links dinosaurs and birds, a furcula (a wishbone). Only two kinds of animals have a furcula: meat-eating dinosaurs and birds. **Theory:** Shared features, like the furcula, indicate to scientists that the two groups are closely related. Some paleontologists theorize that birds are living dinosaurs. For a long time scientists classified dinosaurs as reptiles and birds as birds, but recent fossil discoveries of both birds and dinosaurs have shaken up this "family tree". Birds have moved to a branch that also includes *T. rex*. This connections means birds are living dinosaurs.

Observation: There is a row of holes in Sue's lower jaw. **Theory:** Initially scientists theorized that another dinosaur had bitten Sue. This theory was rejected because the holes do not match up with the teeth of any dinosaur big enough to bite a *T. rex* and the holes are smooth. Usually bite marks have rough edges and cracks. So what did make these holes? Scientists now think disease or infection caused the holes, but because nobody knows what kinds of diseases dinosaurs had, the exact cause remains a mystery.

Speculation

Speculation is a guess about something that is unknown. It is different from a theory in two important ways: it does not have enough evidence to support it, and it cannot be tested scientifically. Speculation can be a bad thing if we confuse it with fact or theory. On the other hand, it can be a good thing if we use it to exercise our imagination and spark scientific inquiry. Use these unanswered questions about Sue to help you imagine what she looked like when she was alive.

- Was Sue female?
- Was Sue a predator, a scavenger, or both?
- What color was Sue?
- How did Sue use her arms?
- How did Sue interact with other dinosaurs of her time?
- How did Sue communicate with another *T. rex*?

Sue in the Flesh

Investigation Data Sheet

1. Which *facts/observations* did you take into consideration as you worked on your picture? Explain.

2. Which *theories* did you take into consideration as you worked on your picture? Explain.

3. What features of your picture or model depict your *speculation* about what Sue looked like or how she lived? Explain.

4. What additional information about Sue would have been helpful as you were creating your picture?

In the Halls

In The Halls

Introduction

Unearthing the Secrets of Sue is a classroom resource targeting grades 4–8 designed to build off of students' interest in dinosaurs to teach them the process of scientific investigation that goes on behind the scenes at the Museum. This section provides teachers with general information and three activities that they can use to excite and prepare students for the more in-depth course of dinosaur study outlined in the rest of the Guide. These activities, which are adapted for use in the classroom or the Museum, are simpler and less involved than the rest of the activities in the Guide. Therefore, they can be used for a K–8 grade audience. These activities provide younger students who may not be ready to engage in an in-depth study an opportunity to interact and enjoy Sue. They will prepare these students for using the activities in the Guide when they are older.

What is a dinosaur?

Dinosaurs were one of the most successful groups of animals to ever walk the planet. They dominated the landscape for more than 160 million years. There is evidence in the fossil record that dinosaurs roamed all continental landmasses. To understand Sue, we first must learn some basic information about dinosaurs.

Young people and adults often confuse the defining characteristics of a dinosaur. Popular interest in dinosaurs has generated a great deal of excitement but also a great deal of misinformation. Here are four simple rules that can help discern between fact and fiction.

Rule 1: Dinosaurs lived during the Mesozoic Era (250-65 million years ago).

Rule 2: Dinosaurs had legs that came straight down from their bodies. They did not have sprawling legs like some prehistoric or modern reptiles (e.g., crocodiles and alligators).

Rule 3: Dinosaurs lived on land. They did not have wings to fly or fins to swim. For example, pterosaurs, pliosaurs, plesiosaurs, ichthyosaurs, and their relatives are NOT dinosaurs.

Rule 4: Dinosaur skeletons have unique features that make them different from other reptiles. For example:

- The hip bones are attached to at least three fused vertebrae.
- The shoulder blade is at least three times as long as it is wide.
- The shoulder socket faces backward.
- The hip socket has a hole through it.
- The top of the femur is ball-shaped with a narrow neck attaching it at an angle to the rest of the femur.
- The femur is usually shorter than the tibia.
- The fibula is very small compared to the tibia.
- One of the ankle bones has a projection that extends toward the tibia.

What kinds of dinosaurs are there?

There are lots of different kinds of dinosaurs. In fact, new dinosaurs are being discovered every year, so the exact number of species is constantly changing. Even so, dinosaurs can generally be divided into two groups: ornithischians (“bird-hipped” dinosaurs) and saurischians (“lizard-hipped” dinosaurs). These terms first were defined in the last half of the 19th century and are based only on the appearance of dinosaur hip bones. They do not imply that lizards evolved from lizard-hipped dinosaurs or that birds evolved from bird-hipped dinosaurs. In fact, current scientific evidence tells us that birds evolved from lizard-hipped dinosaurs!

Saurischians

Saurischians include two main groups of dinosaurs: theropods and sauropods. As far as we can tell, all theropods were carnivorous and walked on two legs. Some were the size of a chicken (like *Compsognathus*), while others were the size of an elephant (like *Tyrannosaurus*). A branch of theropods eventually gave rise to the birds.

The other main group of saurischians are the sauropods. Sauropods were large dinosaurs that walked on four legs and had relatively long necks, small heads, and long tails. The group includes dinosaurs like *Apatosaurus* and *Brachiosaurus*. Sauropods were the largest dinosaurs known, some of which probably weighed more than ten elephants. Closely related to sauropods are a group of dinosaurs called the prosauropods. Prosauropods like *Plateosaurus* were similar to sauropods but were smaller and had shorter necks and tails.

Ornithischians

Ornithischians are very diverse and include many of the more familiar dinosaurs. Scientists think all ornithischians were herbivorous (plant-eaters), and many of the characteristics of ornithischians enabled them to process plant material better. These adaptations included a horny beak for cropping stems and leaves and rows of teeth with expanded, overlapping crowns for grinding up those leaves and stems.

Stegosaurs, ankylosaurs, nodosaurs, and a few other dinosaurs form a group of ornithischians known as armored dinosaurs (thyreophorans) – all of them had some sort of bony armor formed within the skin. *Stegosaurus*, a typical stegosaur, had two rows of plates that extended down its back and a set of pointed spikes on its tail. Nodosaurs and ankylosaurs were almost completely covered in bony elements (known as scutes). These were fairly flat and gave these animals an appearance similar to that of a giant armadillo or tortoise.

Another group of ornithischians includes the horned dinosaurs (ceratopsians) such as *Triceratops*. These large herbivores were very common in the Cretaceous and showed a variety of frill shapes (the frill is the bony collar around the neck) and horn arrangements. Pachycephalosaurs, dinosaurs that walked on two legs and had very thick skulls, are closely related to the horned dinosaurs. Some scientists think pachycephalosaurs might have butted heads like modern sheep do.

The last major group of ornithischians are the ornithopods ("bird-footed" ornithischians). Ornithopods probably alternated between walking on two and four legs and were well-adapted for processing plants. The most diverse and abundant group of ornithopods were the duck-billed dinosaurs, also known as hadrosaurs. These were very abundant at the end of the Cretaceous in North America. Ornithopods also include dinosaurs like *Iguanodon*, one of the first dinosaurs known to science.

How do we know about dinosaurs?

How do we know about animals and plants that inhabited the earth before our time? Fossils! Fossils are any evidence of past life. The word comes to us from the Latin word *fossilis*, which means "dug up."

Careful study of fossils and the sediments in which they are discovered can tell us a great deal about the life and death of the organisms they represent. In order for the remains of a dinosaur to be preserved as a fossil and studied, a unique series of events must take place.

- Following death, a dinosaur's remains must be left relatively undisturbed by scavengers.
- The dinosaur's skin and flesh rot away as the animal is buried in sediment. Remains must be quickly buried to prevent total disintegration.
- The sediments surrounding the dinosaur remains solidify, which locks the skeleton in the ground. Minerals from percolating water fill some of the small spaces in the bone and/or replace some of the original minerals in the bone.
- Movements of the earth's crust eventually elevate the rock containing the dinosaur remains, and erosion re-exposes the fossilized bones. Bones are recognized, unearthed, and studied.

Information about dinosaurs can be preserved in a variety of ways. Simple preservation, mineralization and petrification preserve the detailed structure of bones and teeth. Additionally, molds and casts of bones can form naturally but preserve only evidence of the surface anatomy. Through trace fossils, scientists can gather information about dinosaur behavior.

Simple Preservation

In some instances, bones can be preserved in nearly their original condition. These remains are usually light and crumbly and retain their original chemical composition. Usually, such bones are only thousands of years old. Since dinosaurs are millions of years old, their bones are not preserved through simple preservation. Teeth are an exception. They are similar to bone but are made of a much harder substance, enamel. Because enamel is so hard, dinosaur teeth are commonly preserved through simple preservation. Under very special circumstances, soft tissues can also be preserved through simple preservation. A woolly mammoth frozen in permafrost or a ground sloth mummified (dried out) in a desert cave retains its skin, hair, and other parts of the body.

Mineralization

Dinosaur bones are most commonly preserved through a process known as mineralization (or permineralization). Sue's bones are mineralized. Minerals fill the very small spaces once occupied by soft tissues when the dinosaur was alive, but the original bone is still present. The larger spaces, once occupied by blood vessels, usually remain unfilled. The resulting fossil is much heavier (and usually stronger) than the original bone but still preserves the original microscopic structure. If you lick a mineralized bone, moisture from your tongue is sucked into the larger spaces that are still present. As a result, your tongue feels like it is sticking to the bone. Scientists use this technique in the field to distinguish fossilized bone from rock.

Petrification

A bone is considered petrified when new minerals have replaced all of the original bone. The original structure of the bone is preserved, but none of the original substance is preserved. Usually all of the spaces in the bone are also filled by minerals. Petrified dinosaur bones are very heavy, usually much heavier than mineralized bones. A part of a fossil tree trunk or branch that has been completely mineralized is known as petrified wood.

Natural Casts and Molds

Acidic water may seep into the rock and completely dissolve the dinosaur bones before they have mineralized. If the sediments surrounding the bones have already become solid, the resulting space will preserve the surface structure of the original bones. This space is known as a natural mold. If new mineral deposits later fill this space, a natural cast can form. This cast is an exact replica of the original bones but does not preserve any internal microscopic structure. If the entire body of the dinosaur is buried before it decomposes, a mold or cast of dinosaur skin can form. This is very rare. Dinosaur bones are not commonly preserved as molds or casts, but fossilized sea shells are often preserved this way.

Trace Fossils

This type of fossil does not preserve any part of the dinosaur itself. Rather, it records information about dinosaur activity. Trace fossils can include things like footprints and trackways. By studying these types of trace fossils, scientists can learn about how dinosaurs moved and, sometimes, whether or not they traveled in herds. Coprolites are another type of trace fossil - they are the preserved remains of dinosaur droppings and provide evidence of what dinosaurs ate.

When did dinosaurs live?

Everyone knows that dinosaurs are no longer alive and that they went extinct a long time ago. But did you ever stop to think about how long ago they went extinct? Or how long they were around? Dinosaurs were a very successful group of animals and were the dominant land animals for millions of years. But not all of them lived at the same time. New types of dinosaurs were constantly evolving during their reign, and at the same time, other dinosaurs were going extinct. In order to understand when different types of dinosaurs were alive, it is important to understand a little bit about geologic time.

Geologic time is usually measured in millions of years. That is because most processes like mountain building, erosion, and evolution act very slowly. Even so, the history of the earth includes many millions of years—some 4–5 thousand of them (which equals 4–5 billion years.) For most of this time, there was no life on earth. Even after life evolved, it was a long time before life became more complex than simple one-celled plants and animals. Large, complex animals have only been around for 540 million years—or about one tenth of the history of the earth!

Of this past 540 million years, dinosaurs were around for about 160 million years—about 29% of the time that complex life has been abundant on earth. In comparison, humans have been around only a couple million years—less than 1% of the time complex multicellular life has been abundant.

Dinosaurs lived during the Mesozoic Era. It began 250 million years ago and ended 65 million years ago when the dinosaurs went extinct. Dinosaurs were not alive this entire time but first evolved near the beginning of the Mesozoic during a period of time known as the Triassic Period. The Triassic is one of three Periods that make up the Mesozoic Era. Each Period in geologic time is marked by a major faunal change.

During the Triassic, dinosaurs lived with several other groups of reptile-like animals. At this time, dinosaurs were generally small and not as diverse as they were later. Some of the earliest known dinosaurs include the meat-eating dinosaurs *Coelophysis*, *Herrerasaurus* and *Eoraptor* and the plant-eating dinosaurs *Plateosaurus* and *Pisanosaurus*.

The middle part of the Mesozoic is known as the Jurassic Period. This name has become very familiar to people due to the popular movie, "Jurassic Park". However, the movie included dinosaurs both from the Jurassic Period and from the Cretaceous Period, the last part of the Mesozoic! Most people are not familiar with the wide variety of dinosaurs that lived during the Jurassic. Frequently, the general public only recognizes prosauropods from the earliest part of the Jurassic and sauropods like *Apatosaurus*, *Diplodocus*, and *Brachiosaurus* that lived near the end of the Jurassic. Other plant-eating dinosaurs included *Stegosaurus* and heterodontosaurs (small ornithischians). The main predators at this time were big theropods like *Allosaurus*, *Ceratosaurus*, and *Megalosaurus*.

You are probably much more familiar with dinosaurs that lived during the Cretaceous Period, the last part of the Mesozoic. The Cretaceous Period was also the longest part of the Mesozoic, lasting much longer than either the Triassic or Jurassic Periods. Therefore, dinosaurs that lived in the early part of the Cretaceous were separated by millions of years from those living in the late part of the Cretaceous. Sue (and all tyrannosaurids) are known only from the last part of the Cretaceous, some 65–75 million years ago. In North America, she lived alongside other dinosaurs such as *Triceratops*, duck-billed dinosaurs, pachycephalosaurs, and smaller meat-eating dinosaurs.

Humans did not evolve until a couple million years ago at the end of the Cenozoic Era. The Cenozoic is also known as the "Age of Mammals" and includes all time between now and when the dinosaurs went extinct. Although Sue was separated from the first humans by about 65 million years, Sue lived closer in time to the earliest humans than she did to the earliest dinosaurs (which come from rocks that formed about 150 million years before Sue lived!) Humans will have to live on earth many more millions of years to rival the dynasty of the dinosaurs.

A Strand of Time

Activity Description:

By constructing a timeline of life on earth, students examine the scale of geologic time, which in turn allows them to comprehend how long and how long ago dinosaurs like *Tyrannosaurus rex* roamed the earth.

Grade Level:

K–8

National Science Goals:

Content Standard C: Life Science

Diversity and adaptation of organisms

Content Standard D: Earth and Space Science

Earth's history

Illinois State Standards:

English Language Arts

State Goal 1: Read with understanding and fluency.

A. Apply word analysis and vocabulary skills to comprehend selections.

- Late Elementary –2b
- Middle School –3b

C. Comprehend a broad range of reading materials.

- Late Elementary –2a, 2f
- Middle School –3a, 3f

State Goal 3: Write to communicate for a variety of purposes.

C. Compose ideas in writing to accomplish a variety of purposes.

- Late Elementary –2a
- Middle School –3a

State Goal 4: Listen and speak effectively in a variety of situations.

A. Listen effectively in formal and informal situations

- Late Elementary –2b
- Middle School –3b

Science

State Goal 11: Understand the process of scientific inquiry and technological designs to investigate questions, conduct experiments and solve problems.

G. Know and apply the concepts, principles and processes of scientific inquiry.

- Late Elementary –2a, 2b, 2d, 2e
- Middle School –3a, 3c, 3f, 3g

State Goal 12: Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space science.

A. Know and apply concepts that explain how living things function, adapt and change.

- Middle School –3c

Materials:

- Investigation Data Sheet-Note that two different Investigation Data Sheets are included, one for K-2 and another for 3-8.
- Rulers
- String-Thirty feet long
- Masking tape
- Colored pencils, markers, or crayons
- Construction paper or drawing paper

Time: 45 min to 1½ hrs

Procedure:**Grades K–2**

1. Locate a hall that is at least 30 feet long.
2. Share the timeline events with the students.
3. Provide students with a string that already has each event mapped out.
4. Assign each student or teams of students to an event on the timeline.
5. Ask students to draw pictures that represent their assigned event.
6. Have students attach their picture to the string in the proper location. Have students find their events' position on the timeline by matching their picture with the events already mapped out on the time line.
7. Show students where Sue belongs on the timeline.
8. As a follow-up activity, have students construct a class time line. Each day have students take turns adding one memorable class event to the class timeline.

Grades 3–8

1. Locate a hall that is at least 30 feet long.
2. Give each student an Investigation Data Sheet.
3. Have students mark off each foot of the string with a knot or a piece of tape.
4. Assign each student or teams of students to an event on the timeline.
5. Ask students to draw pictures that represent their assigned event.
6. Have students attach their picture to the string in the proper location. Have students determine their events' location by using the distance measurements on the Investigation Data Sheet. Have the student that represents the beginning of earth's history go to the end of the string, then instruct the other students to find their places on the time line.
7. Ask students where they would put Sue on the timeline? (Hint: *Tyrannosaurus rex* lived on the earth between 67–65 million years ago.)
8. Have students answer the Evaluation Questions on the Investigation Data Sheet.
9. As a follow-up activity, have students construct a time line of their own lives.

A Strand of Time

Investigation Data Sheet (K-2)

Make two copies of this page, and then cut out each event. Attach one complete set of events to the timeline, making sure to place each event at the appropriate location (see #3–8 Investigation Data Sheet for measurements). Distribute the other set to students. Each student will use their assigned event to create a drawing for the class timeline of earth's history.

Earth

(4.57 billion years ago)

Algae

(3.8 billion years ago)

Worms

(540 million years ago)

Fish

(480 million years ago)

Land Plants

(400 million years ago)

Reptiles

(330 million years ago)

First Dinosaurs

(225 million years ago)

Birds

(150 million years ago)

Flowers

(140 million years ago)

Dinosaurs Die

(65 million years ago)

Humans

(2.4 million years ago)

A Strand of Time

Investigation Data Sheet (Grades 3–8)

Use the events and measurements on this page to create a timeline of the earth's history.

| Event | Years Ago | Distance on Timeline |
|--|------------------|-----------------------------|
| Earth forms | 4.57 billion | 9.14 meters / 30 feet |
| Life emerges | 3.8 billion | 7.6 meters / 25 feet |
| Bacteria, algae, and fungi abundant | 3 billion | 6.1 meters / 20 feet |
| Sponges, worms, and jellyfish abundant | 540 million | 1.1 meters / 3.5 feet |
| First fish appear | 480 million | 98 centimeters / 3.2 feet |
| First land plants | 400 million | 79 centimeters / 2.6 feet |
| First amphibians | 360 million | 73 centimeters / 2.4 feet |
| First reptiles | 330 million | 67 centimeters / 2.2 feet |
| Dinosaurs appear | 225 million | 46 centimeters / 1.5 feet |
| Dinosaurs become abundant & birds appear | 160 million | 30 centimeters / 1 feet |
| Flowering plants appear | 140 million | 27 centimeters / 11 inches |
| Dinosaurs are extinct | 65 million | 13 centimeters / 5 inches |
| Mammals become abundant | 50 million | 10 centimeters / 4 inches |
| First humans appear | 2.4 million | .5 centimeter / 2 inches |

The Puzzling Pelvis

Background:

Scientists use the pelvis to classify dinosaurs. All dinosaurs have one of two distinct pelvic bone arrangements. One group has lizard-like hips (**sauroischian**), and the other has more bird-like hips (**ornithischian**). There are three bones that make up the pelvis. They include the ilium, the ischium, and the pubis. The **ilium** is the uppermost of the three major bones. The **ischium** is the bone directly beneath the ilium facing down and to the rear. The location of the **pubis** differs depending on the type of dinosaur. In **sauroischians**, the pubis is directly beneath the front of the ilium facing down and forward, and in **ornithischians**, the pubis is the bone directly beneath the ilium and the ischium, and it faces down and to the rear.

Activity Description:

Students learn the difference between bird-hipped (**ornithischian**) and lizard-hipped (**sauroischian**) dinosaurs by constructing pelvis models and using them to complete an identification exercise. This activity allows students to determine which dinosaurs are most closely related to Sue.

Grade Level:

K–8

National Science Goals:

Content Standard A: Science as Inquiry

Abilities necessary to do scientific inquiry

- Design and conduct a scientific investigation
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.

Content Standard C: Life Science

Diversity and adaptation of organisms

Content Standard D: Earth and Space Science

Earth's history

Illinois State Standards:

English Language Arts

State Goal 1: Read with understanding and fluency.

- A. Apply word analysis and vocabulary skills to comprehend selections.
- Late Elementary -2b
 - Middle School -3b
- C. Comprehend a broad range of reading materials.
- Late Elementary -2a, 2f
 - Middle School -3a, 3f

State Goal 3: Write to communicate for a variety of purposes.

C. Compose ideas in writing to accomplish a variety of purposes.

- Late Elementary –2a
- Middle School –3a

State Goal 4: Listen and speak effectively in a variety of situations.

A. Listen effectively in formal and informal situations.

- Late Elementary –2b
- Middle School –3b

Science

State Goal 11: Understand the process of scientific inquiry and technological designs to investigate questions, conduct experiments and solve problems.

A. Know and apply the concepts, principles and processes of scientific inquiry.

- Late Elementary –2a, 2b, 2d, 2e
- Middle School –3a, 3c, 3f, 3g

State Goal 12: Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences.

A. Know and apply concepts that explain how living things function, adapt and change.

Middle School –3c

Materials:

- Investigation Data Sheet
- Scissors
- Crayons or markers
- Tape or staplers

Time: 1–1½ hours

Teacher Preparation and Suggestions:

1. Review the dinosaur classification section of the *In the Halls* Background Information.

Procedure:**Grades K–2**

1. For younger students use the patterns provided on the Investigation Data Sheet to make models of a lizard-hipped pelvis and a bird-hipped pelvis*. Show students each type of pelvis. Alternatively, give half of your class two copies each of the lizard-hipped pelvis and the other half two copies each of the bird-hipped pelvis. Have students color the three bones of each pelvis as follows: 1=red, 2=yellow, and 3=green.
2. Direct students to cut out their pelvis patterns. Once they have completed cutting out the pattern, assemble the pelvis for them.
3. Ask students to compare the shapes of the two red bones, the two yellow bones, and two green bones to discover the difference between the two types of hips.
4. Ask students to identify the location of Sue's pelvis on the skeleton.
5. Ask students to identify whether Sue is lizard-hipped or bird-hipped.

***Note** –For sturdier pelvis models, trace the patterns on poster board or old file folders.

Grades 3–8

1. Give each student two copies of the two pelvis patterns*, and ask them to color the three bones of each pelvis as follows: pubis=red, ischium=yellow, and ilium=green. Have students identify the ilium, ischium, and pubis on each model.
2. Have the students cut out and assemble a saurischian and an ornithischian pelvis using these directions:
 - Cut out two saurischian pelvis patterns and two ornithischian pelvis patterns.
 - Cut out the hip socket on all four sheets and the small triangle opening on both ornithischian patterns.
 - Tape the two sides of the pelvis together with small pieces of tape at points A and B.
 - Cut out and fold one pelvic brace as indicated.
 - Tape the pelvic brace in between the sides of the pelvis at point C.
 - Fold the crest on the ornithischian pattern ilium outward and down on each side.
3. Discuss the differences and similarities between the two pelvis models. Make sure that each student realizes that the pelvic characteristic that distinguishes the two groups of dinosaurs is the position of the pubis. In saurischian dinosaurs the pubis points forward. The pubis of ornithischian dinosaurs points backwards.
4. Ask students to examine other dinosaurs in the Museum and to identify one saurischian species and one ornithischian species.
5. For a follow-up activity have students complete the Pelvis Classification Exercise using their pelvis models.

Answer Key for Pelvis Identification Exercise:

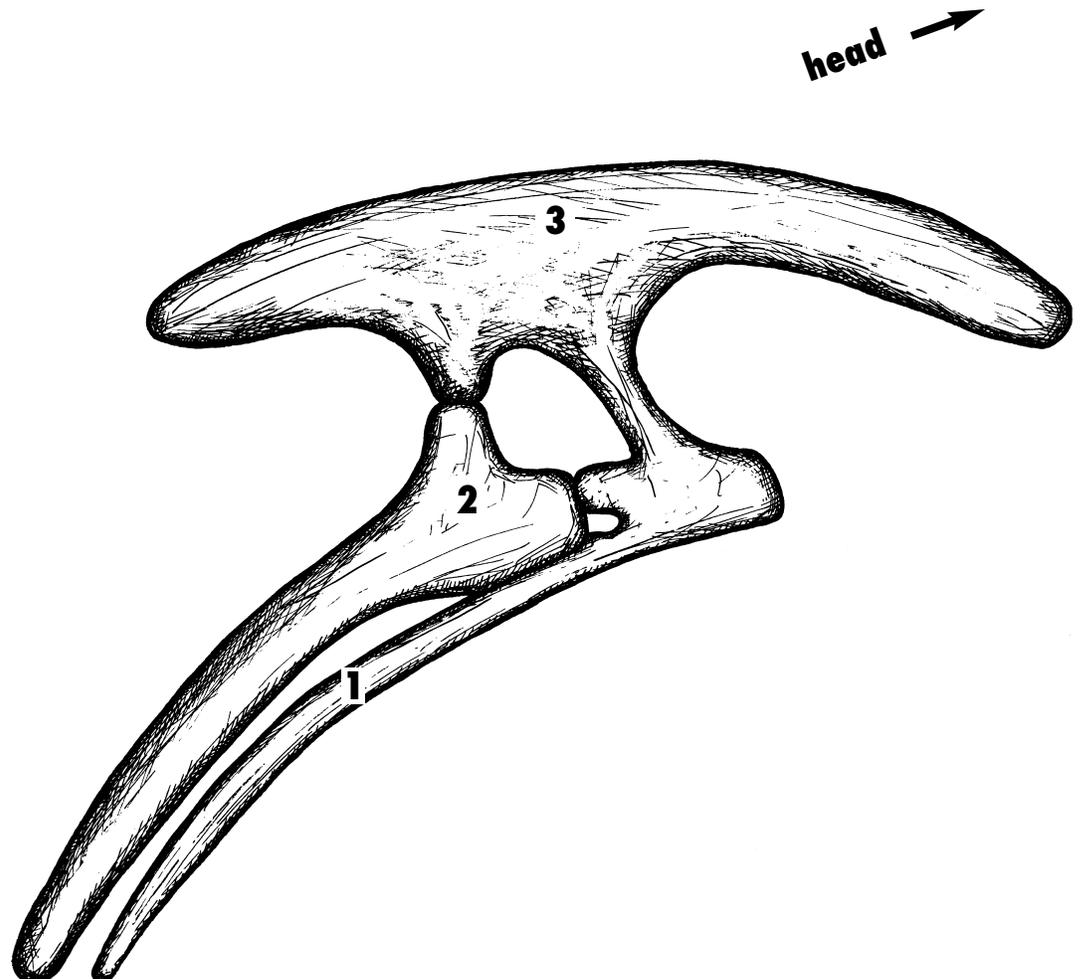
1. *Stegosaurus* – Ornithischian
2. *Deinonychus* – Saurischian
3. *Brachiosaurus* – Saurischian
4. *Triceratops* – Ornithischian

The Puzzling Pelvis

Investigation Data Sheet (Grades K–2)

Bird-hipped Pelvis Pattern

Heterodontosaurus



Color the Bones as Follows:

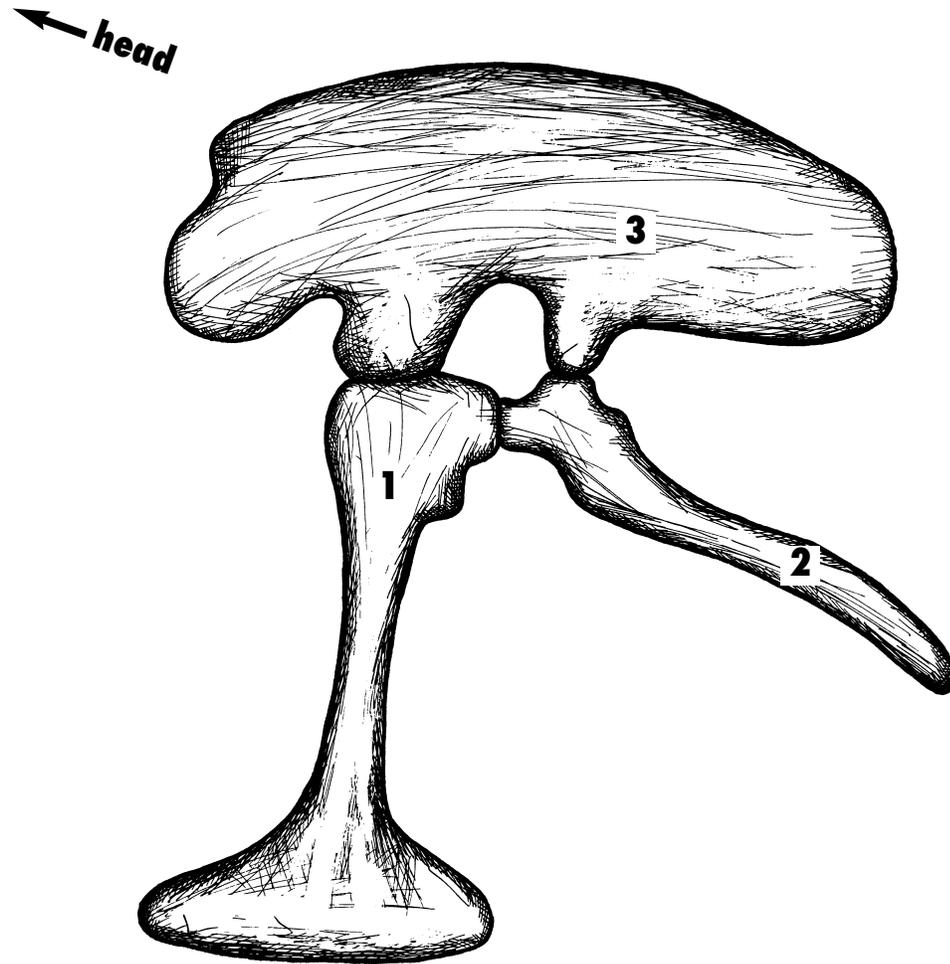
- 1 = Red
- 2 = Yellow
- 3 = Green

The Puzzling Pelvis

Investigation Data Sheet (Grades K–2)

Lizard-hipped Pelvis Pattern

Tyrannosaurus rex



Color the Bones as Follows:

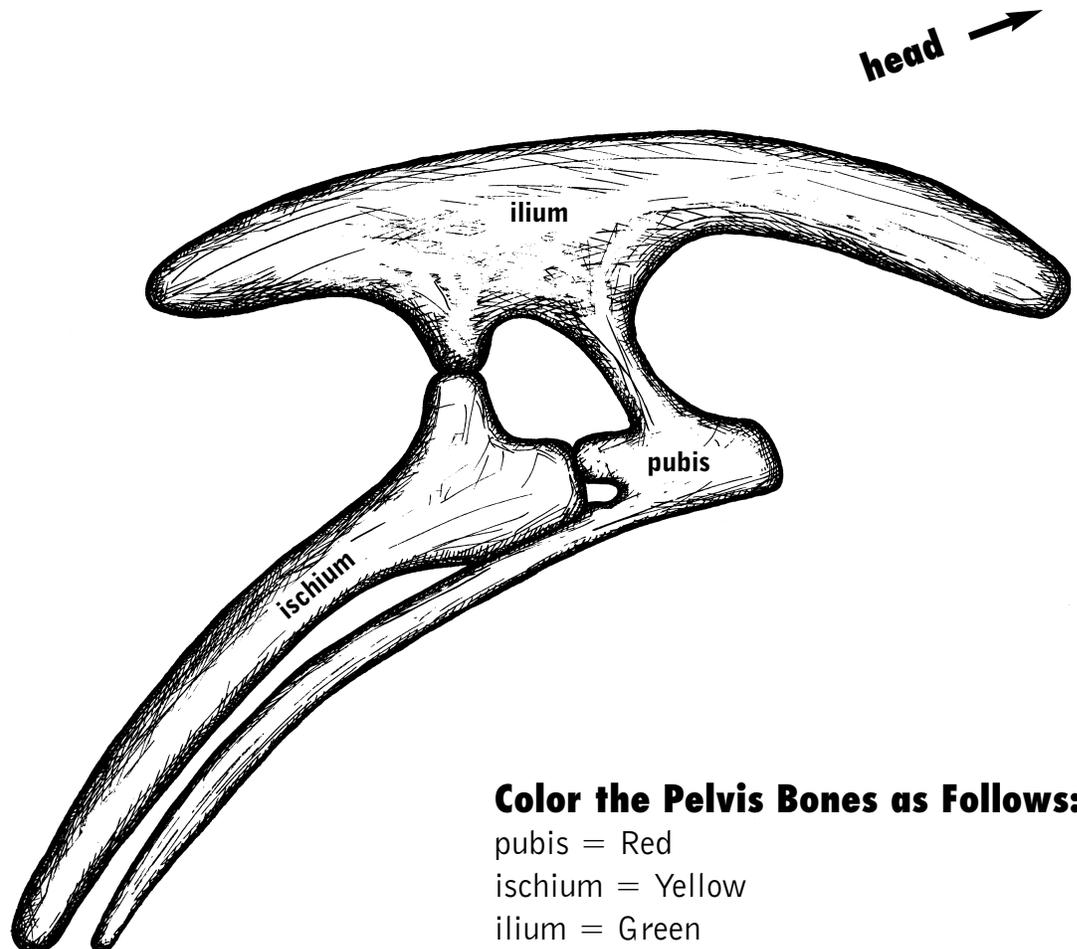
- 1 = Red
- 2 = Yellow
- 3 = Green

The Puzzling Pelvis

Investigation Data Sheet (Grades 3–8)

Ornithischian (bird-hipped) Pelvis Pattern

Heterodontosaurus



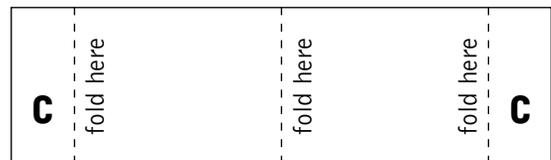
Color the Pelvis Bones as Follows:

pubis = Red

ischium = Yellow

ilium = Green

Pelvic Brace

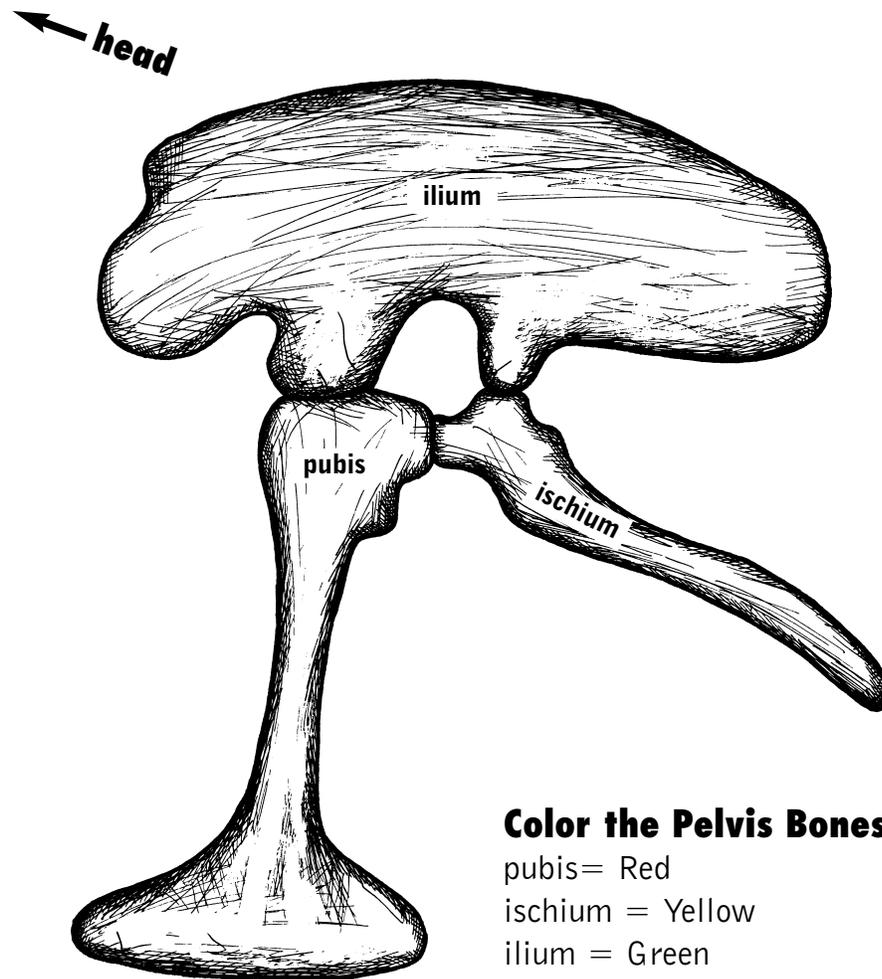


The Puzzling Pelvis

Investigation Data Sheet (Grades 3–8)

Saurischian (lizard-hipped) Pelvis Pattern

Tyrannosaurus rex



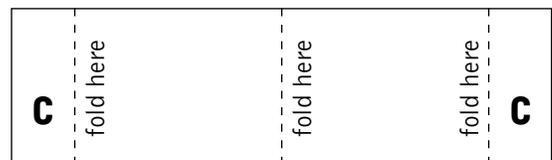
Color the Pelvis Bones as Follows:

pubis = Red

ischium = Yellow

ilium = Green

Pelvic Brace



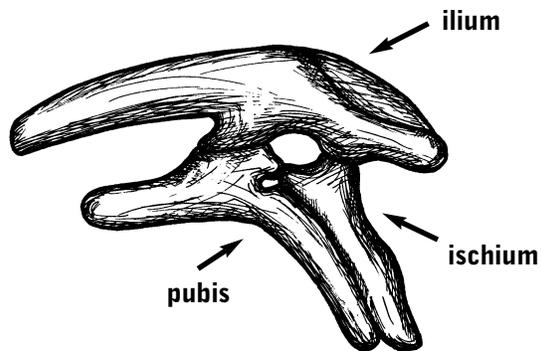
The Puzzling Pelvis

Investigation Data Sheet

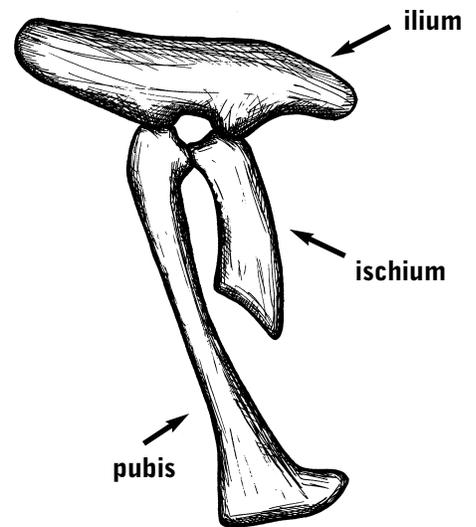
Dinosaur Pelvis Classification Exercise (Grades 3–8)

Use your saurischian and ornithischian pelvis models to classify the pelvises below.

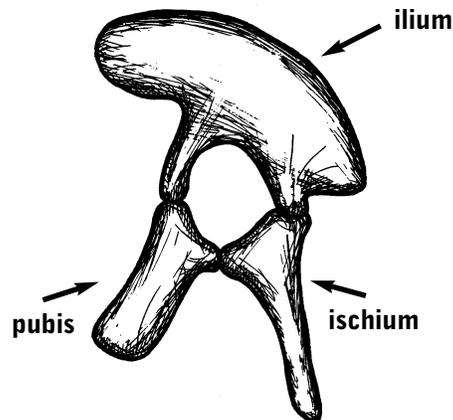
1. _____
Stegosaurus



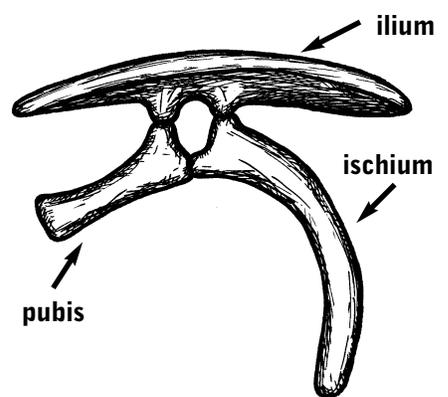
2. _____
Deinonychus



3. _____
Brachiosaurus



4. _____
Triceratops



What's Your Hypothesis?

Activity Description:

Students make and record observations of Sue while learning her anatomy. Using their observations, students formulate hypotheses that attempt to answer questions about Sue's anatomy. Finally, they investigate the Sue exhibition to discover how scientists used observations to form theories about those same questions.

Grade Level:

K–8

National Science Goals:

Content Standard A: Science as Inquiry

Abilities necessary to do scientific inquiry

- Design and conduct a scientific investigation.
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.

Content Standard C: Life Science

Diversity and adaptation of organisms

Content Standard D: Earth and Space Science

Earth's history

Illinois State Standards:

English Language Arts

State Goal 1: Read with understanding and fluency.

- A. Apply word analysis and vocabulary skills to comprehend selections.
 - Late Elementary –2b
 - Middle School –3b
- C. Comprehend a broad range of reading materials.
 - Late Elementary –2a, 2f
 - Middle School –3a, 3f

State Goal 3: Write to communicate for a variety of purposes.

- C. Compose ideas in writing to accomplish a variety of purposes.
 - Late Elementary –2a
 - Middle School –3a

State Goal 4: Listen and speak effectively in a variety of situations.

- A. Listen effectively in formal and informal situations.
 - Late Elementary –2b
 - Middle School –3b

Science

State Goal 11: *Understand the process of scientific inquiry and technological designs to investigate questions, conduct experiments and solve problems.*

- A. Know and apply the concepts, principles and processes of scientific inquiry.
- Late Elementary –2a, 2b, 2d, 2e
 - Middle School –3a, 3c, 3f, 3g

State Goal 13: *Understand the relationships among science technology and society in historical and contemporary contexts.*

- B. Know and apply concepts that describe the interaction between science, technology and society.
- Late Elementary –2c
 - Middle School –3c

Materials:

- Investigation Data Sheet
- Pencils or pens

Time: 30 min to 1 hr

Procedure:

Grades K–2

1. Ask students what they notice (observe) about Sue. Encourage them to be detailed and specific.
2. Have students speculate about how Sue lived and behaved based on what they see.
3. As a follow-up activity, have students use their observations and speculation as a foundation for a class story about Sue. Assign each student a section of the story to illustrate.

Grades 3–8

1. If you did not do the Excavation Extravaganza activity with your class, please read through the Extension Activity, Introducing Observation and Hypothesis. It includes ideas about how to introduce your students to making observations and hypotheses.
2. Ask students to examine Sue and make observations.
3. Have students record their observations on their Investigation Data Sheet, #1.
4. Have students use their observations to formulate hypotheses about Sue.
5. Next, have students speculate about possible interpretations of the observations made by scientists.
6. Introduce students to the term theory. A theory is an explanation of data based on observations. A theory can be tested scientifically. Inform students that scientists have developed theories for their observations. Have students use the exhibition to identify these theories.
7. Suggest to their teachers the following follow-up activity. Have students discuss similarities and differences between their hypotheses and theories proposed in the exhibition.

Investigation Data Sheet Answers:

Scientists' Sue theories, according to the Exhibition

3. Observation: There is a row of holes in Sue's lower jaw.

Initially scientists theorized that another dinosaur had bitten Sue. This theory was rejected because the holes do not match up with the teeth of any dinosaur big enough to bite a T. rex and the holes are smooth. Usually bite marks have rough edges and cracks. So what did make these holes? Scientists now think disease or infection caused the holes, but because nobody knows what kinds of disease dinosaurs had, the exact cause remains a mystery.

4. Observation: Sue has very small forelimbs.

Scientists do not have enough information to formulate a theory about how Sue used her small forelimbs. Sue's right arm is only the second Tyrannosaurus rex forelimb ever found. Until more research can be done, the forelimbs will remain a mystery. Scientists can only speculate about how T. rex used its tiny forelimbs.

Observation: Birds and meat eating dinosaurs like Sue share many features.

A growing number of paleontologists support the theory that birds are actually living, feathered dinosaurs. For a long time scientists linked dinosaurs and reptiles together. But recent discoveries have turned up evidence of a stronger link between birds and dinosaurs. Sue's skeleton provided a key piece of the puzzle that links dinosaurs and birds—a wishbone.

What's your Hypothesis?

Investigation Data Sheet (Grades 3–8)

1. After spending a few minutes examining Sue, record detailed and descriptive observations.

2. Based on your observations, develop hypotheses about Sue.

Now that you have made your own observations, consider the following observations of scientists researching Sue. Speculate about what these observations might reveal about Sue.

3. Observation: There is a row of holes in Sue's lower jaw. Speculate about this observation.

According to the exhibition, what is the scientists' theory based on this observation?

4. Observation: Sue has very small forelimbs. Speculate about this observation.

According to the exhibition, what is the scientists' theory based on this observation?

5. Observation: Birds and meat eating dinosaurs like Sue share many features.

According to the exhibition, what is the scientists' theory based on this observation?

Post-Trip Questions

1. How are your hypotheses similar to the theories proposed in the exhibition?
2. How are your hypotheses different from the theories proposed in the exhibition?
3. Why do theories change over time?
4. What questions do you still have about Sue?

Careers

Careers in Science: The People Behind Sue

Museum visitors are drawn to dinosaur specimens because they are fascinating representations of past life on earth. Few people realize that these displays are the product of many talented individuals, each with very specialized skills.

Curator

Responsible for the systematic arrangement, maintenance, study, and loan of specimens in the Museum collection.

Scientific Researcher

Documents and describes the physical features of a specimen and establishes relationships between living and extinct animals.

Collection Manager

Coordinates the preparation, storage, arrangement, documentation, loan, and study of Museum specimens.

Fossil Preparator

Cleans, reconstructs and repairs fossil specimens under the guidance of paleontologists.

Museum Photographer

Uses a camera to document field work and Museum specimens. The photographer's work is used for both scientific publications and promotional materials.

Scientific Illustrator

Prepares graphic illustrations for the study of paleontological specimens. The illustrations range from depictions of a single bone to "fleshed out" reconstructions of living animals based on the research of paleontologists.

Exhibit Developer

Uses current scientific information to develop the content of a Museum exhibition. Works closely with scientific, design, and education staff members to produce exhibits that are scientifically accurate, appealing to the eye, and conducive to learning.

Exhibit Designer

Responsible for the overall "look" of an exhibit. Takes concepts and content established by exhibit developers and designs a logical and visually appealing method to convey information to Museum visitors.

Exhibit Production Manager

Executes the construction of Museum exhibits under the guidance of exhibit designers and developers.

Museum Educator

Communicates scientific research to the public through individual interaction, public programs, print, or electronic media.

Volunteer

An unpaid staff person that performs tasks in both public and non-public areas of the Museum. Volunteers usually specialize in a specific area based on their interests and particular talents. Some volunteers work in the scientific areas, and others interact directly with the public.

Glossary

Glossary

Air abrasive tool—A mini sandblaster that blows baking soda. This gentle abrasive removes dirt and other matrix material from the fossils.

Air scribe—A mini jackhammer used for fossil preparation. This tool is used to remove rock from areas where there is no danger of damaging the bone.

Ammonites—Animals related to squid and octopus that were living in the oceans during the time of the dinosaurs. Ammonites had shells and were probably active predators in the open oceans, like the modern-day chambered nautilus.

Articulated—When the bones of a fossilized skeleton are found together in life position. A fossil find in which the specimen is articulated and complete is extremely rare.

Cast—An exact replica of a fossil. Casts of fossils can be used for both display and scientific research.

Cenozoic Era—One of the three divisions of the Phanerozoic Eon. The Cenozoic Era began when the dinosaurs went extinct 65 million years ago and continues to this day. Humans first appeared 2.4 million years ago during the Cenozoic.

Ceratopsians—This group of ornithischians had horns. Ceratopsians include dinosaurs like *Triceratops*. These large herbivores were very common in the Cretaceous and show a variety of frill shapes (the frill is the bony collar around the neck) and horn arrangements.

Coprolites—Fossilized animal droppings.

Cretaceous Period—The period of geologic time spanning 144–65 million years ago. The last period of the Mesozoic Era. During this time many groups of dinosaurs reached their peak. At the end of this period, all dinosaurs became extinct.

Dinosaurs—An extinct group of specialized reptiles that lived on land during the Mesozoic Era.

Erosion—When rock breaks down due to weathering by wind and water.

Excavation—The process of removing a fossil from the site where it was discovered.

Extinction—The death of all members of a species or a group of species.

Femur—The thigh bone.

Fossil—The physical remains or traces of animals or plants that have been preserved by natural means.

Fossil Record—The evidence of prehistoric life. The fossil record includes both the preserved remains of plants and animals and trace fossils such as tracks and coprolites.

Fibula—A lower leg bone.

Furcula—The wishbone. Only two kinds of animals have a furcula: meat-eating dinosaurs and birds.

Geologic map—A map that provides detailed information about the age, composition, and location of rock formations.

Geology—The scientific study of the origin, history, and structure of the earth.

Hypothesis—A prediction based on observations.

Jurassic Period—The second period of the Mesozoic Era spanning 206—144 million years ago. During this period, dinosaurs became abundant and birds appeared.

Matrix—The material in which a fossil is embedded.

Mesozoic Era—The era of geologic time spanning 250—65 million years ago. One of the three major divisions of the Phanerozoic Eon, the period of geologic time in which complex life on earth was abundant. The Mesozoic occurred between Paleozoic Era and the Cenozoic Era. The Mesozoic is divided into the Triassic, Jurassic, and Cretaceous Periods.

Mold—An imprint, like a footprint you make when you walk barefoot in wet sand. Molds are used to make casts of fossils.

Mosasaurus—Large marine lizards that lived during the time of the dinosaurs. Mosasaurs had very long bodies and limbs modified into paddles. Some scientists think mosasaurs ate ammonites.

Observation—Information collected using your five senses. You can show observations to others.

Olfactory bulbs—This is the region of the brain that detects smell.

Ornithischians—This group includes “bird-hipped” dinosaurs. This classification is based only on the appearance of dinosaur hip bones. This diverse group includes many species of dinosaurs that are familiar to most people. Scientists think all ornithischians were herbivores (plant-eaters).

Ornithopods—This group of ornithischians was “bird-footed.” Ornithopods probably alternated between walking on two and four legs and were well adapted for processing plants. The duck-billed dinosaurs, also known as hadrosaurs, and *Iguanodon* are examples of this type of dinosaur

Paleontology—The study of ancient life as contained in the fossil record. A paleontologist is a scientist who is trained in both geology and biology.

Phylogeny—How a group of organisms are genetically related to each other.

Plesiosaurs—Large marine reptiles that lived during the time of the dinosaurs. Plesiosaurs had relatively long necks and small heads, especially as compared to mosasaurs, and had limbs modified into paddles.

Polyester resin—A strong durable material used to make a cast of a fossil.

Preparator—A person who is trained to clean fossils and get them ready for display.

Prosauropods—These dinosaurs were closely related to sauropods. Prosauropods are similar to sauropods but were smaller and had shorter necks and tails. An example of this type of dinosaur is *Plateosaurus*.

Rock composition—The materials that make up a rock.

Saurischians—This group includes “lizard-hipped” dinosaurs. This classification is based only on the appearance of dinosaur hip bones. Saurischians include theropods, sauropods, and prosauropods.

Sauropods—Large dinosaurs that walked on four legs and had relatively long necks, small heads, and long tails. The group includes dinosaurs like *Apatosaurus* and *Brachiosaurus*. Sauropods are the largest known dinosaurs, some of which probably weighed more than 10 elephants.

Sedimentary rock—Rocks that are made up of sedimentary materials like sand or silt.

Speculation—A guess about something that is unknown. It is different from a theory because it does not have enough evidence to support it and it cannot be tested scientifically.

Stapes—The slender bone that connects the eardrum to the inner ear.

Stratum—A layer of sedimentary rock.

Stratigraphic column—A diagram that provides geologic information about the composition, order, and age of strata.

Theory—An explanation of data based on observations. A theory can be tested scientifically.

Theropods—The group of lizard-hipped, meat-eating dinosaurs that walked on two legs. This group includes dinosaurs such as *Tyrannosaurus rex* and *Velociraptor*. Some scientists theorize that theropods gave rise to birds.

Thyreophorans—Stegosaurs, ankylosaurs, nodosaurs, and a few other dinosaurs form a group of ornithischians known as “armored dinosaurs”. All of these dinosaurs have some sort of bony armor formed within the skin.

Tibia—One of two bones that make up the lower leg bone.

Triassic Period—The period of geologic time spanning 250 to 206 million years ago. One of the three periods in the Mesozoic, the time of the dinosaurs. It was during the Triassic that the first dinosaurs appeared.

Vertebra—One of the bones that makes up the spinal column (backbone).

Resources

Where to Find More Information About Dinosaurs

Field Museum Dinosaur Resources

TITLE: *The Field Museum Web Page*

ADDRESS: <http://www.fmnh.org>

DESCRIPTION: Visit the home of Sue. This site covers all the exhibitions and programs at The Field Museum and provides access to current information about Sue.

TITLE: *SUE at The Field Museum*

ADDRESS: <http://www.fmnh.org/sue/default.htm>

DESCRIPTION: This site provides the latest news about Sue, background information about her life and times, and answers to the most frequently asked questions about the world's most famous *T. rex*. From here, the Sue web cam is accessible at http://www.fmnh.org/sue/default_icam.htm. Peer over the shoulder of Field Museum fossil preparators as they uncover prehistoric remains from the solid matrix that entraps them. Zoom in for a more detailed look as they delicately remove material and expose fossils for the first time in millions of years.

TITLE: *Life Over Time*

ADDRESS: <http://www.fmnh.org/exhibits/lot/LOT1.htm>

DESCRIPTION: The online *Life Over Time* exhibition looks at the geological and biological evolution on planet Earth over the past 4.7 billion years. It includes a quick look at the actual exhibition and a teachers' guide that includes classroom activities, an extensive bibliography, and additional resources available through the Museum's Harris Educational Loan Center.

TITLE: *A Dinosaur named Sue: The Find of the Century*

AUTHOR: Fay Robinson with the Science Team of The Field Museum

PUBLISHER: Scholastic Inc.

YEAR: 1999

ISBN: 0439099838

DESCRIPTION: A fascinating 48-page book for young readers that will take them from Sue's discovery in South Dakota to The Field Museum of Chicago. Featuring stunning photographs and original illustrations.

TITLE: *The Field Mouse and the Dinosaur Named Sue*

AUTHOR: Jan Wahl

DESCRIPTION: A picture book that tells the story of a little Field Mouse who arrives at The Field Museum in one of the crates containing Sue's bones. Illustrated by Bob Doucet.

TITLE: *Sue: The Story of the Colossal Fossil; The World's Most Complete T. rex*

DESCRIPTION: The definitive, hardcover, non-fiction book about Sue for middle grades and up that will take Sue from discovery to mounting and research. Written by Pat Relf with the Science Team of The Field Museum.

TITLE: *Dinosongs: Tyrannosaurus Sue, A Cretaceous Concerto*

DESCRIPTION: A charming hardcover gift book and CD of Sue dinosaur poems. Includes the CD of poems read by a celebrity narrator, and the original music of *Tyrannosaurus Sue: A Cretaceous Concerto*.

Books About Dinosaurs
Books for the Young Reader

NF = Nonfiction

F = Fiction

F

TITLE: *Danny and the Dinosaur*

AUTHOR: Syd Hoff

PUBLISHER: HarperTrophy

YEAR: 1993

ISBN #: 0064440028

DESCRIPTION: Danny's adventures with a dinosaur, which thrilled readers years ago, may seem a bit tame compared to today's prehistoric animal fans. However, the simple story, with full color added to Hoff's art, will still capture the hearts of the youngest chapter-book readers.

NF

TITLE: *Digging Up Dinosaurs* (Let's Read and Find Out Books)

AUTHOR: Alike

PUBLISHER: HarperTrophy

YEAR: 1988

ISBN #: 0064450783

DESCRIPTION: With updated text and brand-new, full-color illustrations, this book introduces children to the various types of dinosaurs and then discusses how scientists work together to uncover and preserve fossilized bones.

Books for the Young Reader



- TITLE:** *Dinosaur Bob and His Adventures With the Family Lizardo*
(Reading Rainbow Book)
- AUTHOR:** William Joyce
- PUBLISHER:** Harpercollins Juvenile Books
- YEAR:** 1995
- ISBN #:** 0060210745
- DESCRIPTION:** Seven years after the original publication starring “the most adorable of dinos” (*The New York Times*), Bob is greener and grander than ever. This deluxe edition of the Reading Rainbow feature selection contains seven new, spectacular illustrations, an additional adventure, and a song with arrangement.



- TITLE:** *Fossils Tell of Long Ago*
- AUTHOR:** Alike
- PUBLISHER:** HarperCollins Children’s Books
- YEAR:** 1990
- ISBN #:** 0690048297
- DESCRIPTION:** This useful, simple book examines how fossils are made and contains slight revisions and new color illustrations that include lively children.



- TITLE:** *The Magic School Bus: In the Time of the Dinosaurs*
- AUTHOR:** Joanna Cole
- ILLUSTRATOR:** Bruce Degen
- PUBLISHER:** Scholastic Trade
- YEAR:** 1994
- ISBN #:** 0590446886
- DESCRIPTION:** This time the familiar bus becomes a time machine, taking the class back to the Late Triassic period, then moving forward through the Jurassic and Cretaceous periods to the present for a firsthand view of developments in dinosaur history. This book highlights the *Maiasaura*, some of the very last dinosaurs on earth, who are thought to have cared for their young

Books for the Young Reader



TITLE: *My Visit to the Dinosaurs*
AUTHOR: Alikei
PUBLISHER: Ty Crowell Company
YEAR: 1985
ISBN #: 0690044232
DESCRIPTION: Alikei introduces young children to dinosaurs through a visit to a natural history museum.



TITLE: *Patrick's Dinosaurs*
AUTHOR: Carol Carrick
PUBLISHER: Houghton Mifflin Company
YEAR: 1983
ISBN #: 0899191894
DESCRIPTION: One Saturday while visiting the zoo, Hank tells his brother Patrick all about dinosaurs, and Patrick scares himself by imagining what it would be like if the great creatures were alive today. *Patrick's Dinosaurs* presents a delightful milieu of fact and fantasy that promises to be popular among young dinosaur enthusiasts.



TITLE: *Time Flies*
AUTHOR: Eric Rohmann
PUBLISHER: Crown
YEAR: 1994
ISBN #: 0517595982
DESCRIPTION: In this wordless picture book, Rohmann sets the scene in a natural history museum, where in the dinosaur hall time suddenly shifts into the Age of Reptiles (or were the dinosaurs the ancestors of today's birds?). During a thunderstorm, a bird flies among the dinosaur skeletons in the majestic hall. The scene subtly changes. As the walls become a landscape, the stone columns turn into trees, and the bones flesh out into living creatures. Swallowed by one of the dinosaurs, the bird flies down its throat, only to find the flesh thinning out to the bone framework again and the museum reappearing. The bird flies free again, out of the beast, and out of the building. It's a short trip, but kids fascinated by dinosaurs may enjoy this vicarious voyage back in time. The handsome, atmospheric paintings heighten the drama as they tell their simple and somewhat mysterious short story.

Books for the Beginning Dinosaur Explorer

NF

TITLE: ***Bigger Than T. Rex : The Discovery of the Biggest Meat-Eating Dinosaur Ever Found***

AUTHOR: Don Lessem

ILLUSTRATORS: Robert F. Walters and Greg Wenzel

PUBLISHER: Crown Publishing

YEAR: 1997

ISBN #: 0517709309

DESCRIPTION: From the author of *Digging Up Tyrannosaurus Rex* comes an up-to-the-minute account of a newer and bigger dinosaur discovery: the excavation in Argentina of a new species of meat-eating dinosaur, *Giganotosaurus*, thought to have been larger and more ferocious than *Tyrannosaurus rex*. Full-color photos and realistic illustrations.

NF

TITLE: ***Digging into Dinosaurs*** (Ranger Rick's Naturescope)

AUTHOR: Sandra Stotksy

PUBLISHER: Chelsea House Publishing

YEAR: 1998

ISBN #: 0517883368

DESCRIPTION: As an introduction to paleontology that comes complete with a time scale and full-color illustrations, *Digging into Dinosaurs* allows young readers to explore the amazing world of dinosaurs through informative, fact-filled text and more than twenty-five different hands-on activities.

NF

TITLE: ***Dinosaurs*** (Audubon Society Pocket Guides)

AUTHOR: Joseph E. Wallace

PUBLISHER: Knopf

YEAR: 1993

ISBN #: 067974150X

DESCRIPTION: A detailed guide to dinosaurs that provides up-to-date information about the life cycle, behavior, habitat, anatomy, and habits of eighty species of the ancient reptiles and speculates about the causes of their eventual extinction.

Books for the Beginning Dinosaur Explorer

NF

TITLE: *The Giant Book of T. Rex and Deadly Dinosaurs*
AUTHOR: Jim Pipe
ILLUSTRATOR: James Field
PUBLISHER: Copper Beech Books
YEAR: 1998
ISBN #: 0761307761
DESCRIPTION: This book takes readers into the fascinating world of *Tyrannosaurus rex* and other giant prehistoric hunters to find out how and where they hunted, how they defended themselves, and more. Full color.

NF

TITLE: *New Questions and Answers about Dinosaurs*
AUTHOR: Seymour Simon
ILLUSTRATOR: Jennifer Dewey
PUBLISHER: William Morrow & Company
YEAR: 1990
ISBN #: 0688081959
DESCRIPTION: Seymour Simon, an award-winning author of science books, presents the latest theories and discoveries about dinosaurs with the aid of color illustrations.

NF

TITLE: *The News About Dinosaurs*
AUTHOR: Patricia Lauber
PUBLISHER: Aladdin Paperbacks
YEAR: 1994
ISBN #: 0689718705
DESCRIPTION: Read all about it—the latest news on dinosaurs! An award-winning author of several science books for young people, Lauber explains many of the exciting new theories about dinosaurs that portray them as fast-moving, warm-blooded creatures. *The News About Dinosaurs* is magnificently illustrated in full color.

Books for the Beginning Dinosaur Explorer

NF

- TITLE:** ***Supergiants!: The Biggest Dinosaurs***
AUTHOR: Don Lessem and Rodolfo Coria
ILLUSTRATOR: David Peters
PUBLISHER: Little Brown & Company
YEAR: 1997
ISBN #: 0316521183
DESCRIPTION: This illustrated volume introduces some of the largest prehistoric creatures that have been unearthed to date. Information boxes contain key facts, text that explains the circumstances of the dinosaurs' discovery and retrieval, and the knowledge that scientists have uncovered about their physical attributes and behavior.

NF

- TITLE:** ***Tyrannosaurus*** (American Museum of Natural History)
EDITOR: Mary Ann Lynch
AUTHOR: William Lindsay
PUBLISHER: DK Publishing
YEAR: 1993
ISBN #: 1564581241
DESCRIPTION: This oversized volume explains how the bones of two dinosaurs were discovered and reconstructed for museum display. Striking color photographs of dinosaur models and other artwork make this book very inviting to readers.

Books for the Advanced Dinosaur Explorer

NF

- TITLE:** ***The Complete Idiot's Guide to Dinosaurs***
(Complete Idiot's Guides)
AUTHORS: George R. McGhee, Jay Stevenson, and Kevin Padian
PUBLISHER: Alpha Books
YEAR: 1998
ISBN #: 0028623908
DESCRIPTION: With up-to-date, non-technical insights into the many different species of dinosaurs and details on their physical characteristics, eating habits, and reproductive systems, this fascinating book also takes readers into the realities of DNA testing, cloning, and theories of extinction.

Books for the Advanced Dinosaur Explorer

NF

TITLE: ***Digging Up Tyrannosaurus Rex***
AUTHOR: John R. Horner, Don Lessem, and Don Lessen
PUBLISHER: Crown Publishing
YEAR: 1995
ISBN #: 0517883368
DESCRIPTION: This “superb, fascinating, authoritative firsthand account” (*Science Books & Films*) documents the 1988 discovery and excavation of a unique fossil—a complete *Tyrannosaurus rex* skeleton. Paleontologist John Horner describes how he and his team painstakingly excavated the fossil. Full-color photos and illustrations.

NF

TITLE: ***Dino-Trekking: The Ultimate Dinosaur Lover’s Travel Guide***
AUTHOR: Kelly Milner Halls
PUBLISHER: John Wiley & Sons
YEAR: 1996
ISBN #: 0471114987
DESCRIPTION: This entertaining and fact-filled guide will appeal to dino lovers of all ages and contains over 300 alphabetical listings of dinosaur and prehistoric sites across North America. Each site includes the name, address, phone number, a brief description, a rating and symbols for restrooms, gift shops, food vendors, handicap accessibility, and if there is an admission charge or donation required. The Dino-Shopping Guide provides sources for purchasing all kinds of dinosaur-related products—from party goods to authentic fossils. The piece features an illustrated dino-identifier of 70 prehistoric creatures.

NF

TITLE: ***The Dinosaur Heresies: New Theories Unlocking the Mystery of the Dinosaurs and Their Extinction***
AUTHOR: Robert T. Bakker
PUBLISHER: Kensington Publishing Corporation
YEAR: 1996
ISBN #: 0821756087
DESCRIPTION: For over a century, dinosaurs have been thought of as plodding, dim-witted, giant lizards too awkward and ill-equipped to survive the ravages of environmental change. Bakker offers startling new evidence destined to forever alter the perception of dinosaurs, depicting them as never before imagined: hot-blooded, amazingly agile, and surprisingly intelligent.

Books for the Advanced Dinosaur Explorer

TITLE: ***The Dinosaur Question and Answer Book***
AUTHOR: Sylvia Funston
PUBLISHER: Demco Media
YEAR: 1998
ISBN #: 060613333X
DESCRIPTION: Illustrated with charts, photographs, and illustrations, this book answers the most frequently asked questions about dinosaurs. Although brief, the answers are often fascinating or surprising due to the recent research findings they reflect. A great book for the young dinosaur fan.



TITLE: ***Dinosaurs*** (Audubon Society Pocket Guides)
AUTHOR: Joseph E. Wallace
PUBLISHER: Knopf
YEAR: 1993
ISBN #: 067974150X
DESCRIPTION: A detailed guide to dinosaurs provides up-to-date information about the life cycle, behavior, habitat, anatomy, and habits of eighty species of the ancient reptiles and speculates about the causes of their eventual extinction.



TITLE: ***Raptor Red***
AUTHOR: Robert T. Bakker
PUBLISHER: Bantam Books
YEAR: 1996
ISBN #: 0553575619
DESCRIPTION: A unique novel set in prehistoric Utah and written by a professional paleontologist, the story is told from the point of view of a female dinosaur named Raptor Red, who embarks on a year-long struggle for survival.

Videotapes About Dinosaurs

Videotapes for the Beginning Dinosaur Explorer

TITLE: ***Dinosaurs***

YEAR: 1989

ASIN #: 6303628370

DESCRIPTION: Look closely at these extinct yet mighty creatures. Examine the explosive new controversies surrounding our understanding of their lives, environments, and demise. Experience their breathtaking beauty and astounding impact in *Dinosaurs*, a Smithsonian Video presentation that tells the magnificent tale through the Smithsonian's incomparable collection of fossilized specimens and dramatic recreations.

TITLE: ***Dinosaurs, The—Complete Set***

YEAR: 1993

ASIN #: 6303196179

DESCRIPTION: Each volume in the series is available individually. Individual titles are: "The Monsters Emerge," "Flesh on the Bones," "The Nature of the Beast," and "The Death of the Dinosaur."

Videotapes for the Advanced Dinosaur Explorer

TITLE: ***Dinosaur***

YEAR: 1995

ASIN #: 6303893368

DESCRIPTION: Another fine entry from Dorling Kindersley's Eyewitness series, this video clearly presents and dynamically illustrates numerous facts about those beasts from 65 million years ago. Martin Sheen narrates this program that explores what paleontologists have uncovered in the last 200 years (an important find is made every seven weeks on average). Typical fact: Did you know that all the information on *Tyrannosaurus rex* is attributed to only a dozen skeletal finds before Sue! The varieties of illustrations are truly remarkable and include computer graphics, animations, claymation, and even wonderful low-tech models. Adults are sure to find *Dinosaur* as engaging as younger audiences do.

Videotapes for the Advanced Dinosaur Explorer

TITLE: *Dinosaurs*

YEAR: 1989

ASIN #: 6303628370

DESCRIPTION: Look closely at these extinct yet mighty creatures. Examine the explosive new controversies surrounding our understanding of their lives, environments, and demise. Experience their breathtaking beauty and astounding impact in *Dinosaurs*, a Smithsonian Video presentation that tells the magnificent tale through the Smithsonian's incomparable collection of fossilized specimens and dramatic recreations.

TITLE: *Dinosaurs, The—Complete Set*

YEAR: 1993

ASIN #: 6303196179

DESCRIPTION: Each volume in the series is available individually. Individual titles are: "The Monsters Emerge," "Flesh on the Bones," "The Nature of the Beast," and "The Death of the Dinosaur."

TITLE: *T. Rex Exposed*

YEAR: 1997

ASIN #: 6304794479

DESCRIPTION: He's been mythologized and merchandised like no other dinosaur. Does anyone know the real *Tyrannosaurus rex*—or is he just another misunderstood celebrity? Until recently, everything we knew about this dinosaur king was based on a small collection of bones. Thanks to some astonishing new finds, the mighty carnivore's image is changing. Join a museum crew on a suspenseful dig to uncover one of the most complete *T. rex* specimens ever found, a remarkably preserved skeleton some 40 feet long. Then, hear what the scientists have to say about how this mysterious beast moved, killed, and lived, and what kind of cosmic zap it would have taken to make it die.

Videotapes for the *Advanced Dinosaur Explorer*

- TITLE:** *The World's Greatest Dinosaur Video*
YEAR: 1992
ASIN #: 6302344921
DESCRIPTION: This fun and educational adventure into the world of dinosaurs travels to the four corners of the globe to uncover mysteries hidden for millions of years. The expedition journeys to Africa to explore the legend of a living dinosaur, and visits the Dinosaur National Monument, the Smithsonian Institution, the La Brea Tar Pits in Los Angeles, London's Crystal Palace Park, and limestone caves in New Mexico. The program depicts Saber Tooth Cats, the gigantic *Ultrasaurus*, Woolly Mammoths, and more! Combining live action, animation, and film clips, it recreates all the excitement of prehistoric times when dinosaurs roamed the earth.

Websites About Dinosaurs

Websites for the *Beginning Dinosaur Explorer*

- TITLE:** *Dino Russ's Lair: Illinois State Geological Survey*
ADDRESS: http://128.174.172.76:isgsroot/dinos/dinos_home.html
DESCRIPTION: One-stop shopping for dinosaur resources leads you to digs, eggs, tracks, news—you name it. If you have some questions, don't be afraid to shoot them by Russ.
- TITLE:** *The Dinosauria: Truth Is Stranger than Fiction*
ADDRESS: <http://www.ucmp.berkeley.edu/diapsids/dinosaur.html>
DESCRIPTION: The one-stop dinosaur site is chock full of myth-busting info. Some material may be too advanced for early elementary students, but older kids will find these pages fascinating, and teens will make good use of the large searchable vertebrate catalog.
- TITLE:** *Download a Dinosaur*
ADDRESS: <http://www.rain.org/~philfear/download-a-dinosaur.html>
DESCRIPTION: Do you want to have a dinosaur that you made yourself? This site has four of them that you can download, print, color, and cut out to decorate your room or even a birthday cake.
- TITLE:** *Frequently Asked Questions about Paleontology*
ADDRESS: <http://www.ucmp.berkeley.edu/FAQ/faq.html>
DESCRIPTION: Some of the most common questions about paleontology are answered.

Websites for the Beginning Dinosaur Explorer

- TITLE:** *Paul Sereno's Dinosaur Site*
ADDRESS: <http://dinosaur.uchicago.edu>
DESCRIPTION: Paleontologist Paul Sereno highlights expeditions and discoveries made by him and his team. Information links to photos of fossil preparation. Also, find a list of Sereno's published works along with television documentary schedules.

Websites for the Advanced Dinosaur Explorer

- TITLE:** *Curse of T. Rex* (Nova)
ADDRESS: <http://www.pbs.org/wgbh/nova/trex>
DESCRIPTION: Nova's presentation demonstrates that the dinosaurs weren't alone. They shared the planet with a diverse variety of insects, mammals, and plants. Want to find your own fossil? Find out where to dig for the best luck.

- TITLE:** *Dino Russ's Lair: Illinois State Geological Survey*
ADDRESS: http://128.174.172.76:/isgroot/dinos/dinos_home.html
DESCRIPTION: One-stop shopping for dinosaur resources leads you to digs, eggs, tracks, news—you name it. If you have some questions, don't be afraid to shoot them by Russ.

- TITLE:** *Dinosaur Reference Center*
ADDRESS: <http://www.crl.com/~sarima/dinosaurs>
DESCRIPTION: A little technical perhaps, but if you're really into dinosaurs or need classification, this page can give it to you—in a concise and orderly manner. Find a list of all known dinosaurs alphabetized by genus.

- TITLE:** *Dinosaur Extinction*
ADDRESS: <http://ericir.syr.edu/Projects/Newton/12/Lessons/dinoextn.html>
DESCRIPTION: How could anything so big and powerful simply disappear from the face of the earth? This page attempts to answer this question, addressing the asteroid-impact theory that may have led to the dinosaurs' demise. Experiments target educators and students.

- TITLE:** *The Dinosauria: Truth Is Stranger than Fiction*
ADDRESS: <http://www.ucmp.berkeley.edu/diapsids/dinosaur.html>
DESCRIPTION: The one-stop dinosaur site is chock full of myth-busting info. Some material may be too advanced for early elementary students, but older kids will find these pages fascinating, and teens will make good use of the large searchable vertebrate catalog.

Websites for the Advanced Dinosaur Explorer

TITLE: *Download a Dinosaur*

ADDRESS: <http://www.rain.org/~philfear/download-a-dinosaur.html>

DESCRIPTION: Do you want to have a dinosaur that you made yourself? This site has four of them that you can download, print, color, and cut out to decorate your room or even a birthday cake.

TITLE: *Frequently Asked Questions about Paleontology*

ADDRESS: <http://www.ucmp.berkeley.edu/FAQ/faq.html>

DESCRIPTION: Some of the most common questions about paleontology are answered.

TITLE: *Giganotosaurus*

ADDRESS: <http://www.giganotosaurus.com>

DESCRIPTION: The biggest, the baddest, the largest-known meat-eater to ever walk the planet makes *T. rex* look like a pussycat. Learn more about the creature and take part in a contest and a puzzle.

TITLE: *Journal of Dinosaur Paleontology: Dinosauria*

ADDRESS: <http://www.dinosauria.com/jdp/jdp.htm>

DESCRIPTION: A vast collection of essays, analytical articles and news headlines helps you keep your thumb on research in paleontology. Rich with discoveries, the page is updated frequently to provide the latest stories.

TITLE: *The Paleo Ring*

ADDRESS: <http://www.pitt.edu/~mattf/PaleoRing.html>

DESCRIPTION: The Paleo Ring is devoted to the exploration of paleontology, paleoanthropology, prehistoric archaeology, the evolution of behavior, and evolutionary biology. You can find many dinosaur pages, information on fossils, and a great deal more.

TITLE: *Paul Sereno's Dinosaur Site*

ADDRESS: <http://dinosaur.uchicago.edu>

DESCRIPTION: Paleontologist Paul Sereno highlights expeditions and discoveries made by him and his team. Information links to photos of fossil preparation. Also, find a list of Sereno's published works along with television documentary schedules.

Websites for the Advanced Dinosaur Explorer

TITLE: *The Rex Files: New Scientist*

ADDRESS: <http://rexfiles.newscientist.com>

DESCRIPTION: The truth is out there—if scientists can ever agree on what it is. The purpose of this page is to upset some of the old ideas concerning dinosaurs, replacing them with new theories about evolution, extinction, and thunder-lizard lifestyles.

TITLE: *Tyrannosaurus Rex Exposition: University of California Museum of Paleontology*

ADDRESS: <http://www.ucmp.berkeley.edu/trex/trexp.html>

DESCRIPTION: Of all the dinos that roamed the earth, no other has been as popular as *T. rex*. Learn about your favorite prehistoric carnivore through this online exhibition that discusses anatomy, eating habits, and fossil reconstruction.

Appendix A — Chicago Public School Standards

Chicago Academic Standards

Activities in the Educators' Guide were designed to help Chicago Public School teachers meet Chicago Academic Standards (CAS). Each activity outlines which English Language Arts, Mathematics, and Science Standards it fulfills. For more information about CAS call 773-553-1600. You can also view information about National Science Education Standards online at: <http://www.cps.k12.il.us/Instruction/CAS/>.

Activity: Finding Sue **English Language Arts**

State Goal 1: Read with understanding and fluency.

Late Elementary:

- CAS A—Apply strategic reading behaviors to examine, construct, and extend the meaning of a wide variety of texts to be informed, to perform a task, and for literary experience.
- CAS B—Use a wide variety of word analysis strategies to construct meaning from unfamiliar texts.
- CAS C—Make and support inferences when reading nonfiction text, relating structure, organization, and content to the textual purpose.

Middle School:

- CAS A—Adjust strategies and reading rates according to the nature and purpose of a text to be informed, to perform a task, and for literary experience.
- CAS B—Uses semantic and syntactic cues to construct meaning from texts.
- CAS D—Analyze and evaluate information from expository texts, including public and functional documents.

State Goal 3: Write to communicate for a variety of purposes.

Late Elementary:

- CAS B—Write in a manner that reflects focus, organization, and coherence, using a variety of supporting evidence and elaborative detail.

Middle School:

- CAS B—Write with focus, organization, coherence, and unity in relation to purpose and audience, using a variety of supporting evidence and elaborative detail.

State 4: Listen and speak effectively in a variety of situations.

Late Elementary:

- CAS A—Listen and respond critically to gain knowledge from spoken messages and formal presentations.

Middle School:

- CAS A—Listen and respond analytically and critically to gain knowledge from formal, informal, and media/viewed settings.

State Goal 5: Use the language arts for inquiry and research to acquire, organize, analyze, evaluate, and communicate information.

Late Elementary:

- CAS A—Gather, organize, and integrate information from a variety of print and non-print sources to answer questions and solve problems related to investigation and research.

Middle School:

- Conduct research, individually and cooperatively, analyzing and applying the acquired information to produce presentations.

Mathematics

State Goal 10: Collect, organize, and analyze data using statistical methods to predict results and interpret uncertainty and change in practical applications.

Late Elementary:

- CAS B—Draw conclusions and evaluate arguments based on data analysis and data displays (tables, charts, graphs), verifying reasoning.
- CAS D—Determine the probability of events when there are equally likely outcomes.

Middle School:

- CAS B—Formulate a hypothesis, define the population, collect and analyze data, draw conclusions, and communicate results.
- CAS C—Compare and make predictions based on theoretical probability and relative frequency.

Science

State Goal 11: Have a working knowledge of the processes of scientific inquiry and technological design to investigate questions, conduct experiments, and solve problems.

Late Elementary:

- CAS A—identify problems and derive solutions to demonstrate an understanding of the processes of scientific investigation.
- CAS B—Design and safely conduct scientific investigations to answer questions and test the validity of predictions" making observations, describing procedures, organizing data, drawing reasonable conclusions, and interpreting results.

Middle School:

- CAS A—Analyze data, draw conclusions based on evidence, and report results accurately in a variety of formats.

- CAS B—Demonstrate understanding of scientific processes and apply them to experiments: stating a purpose, developing a hypothesis, designing procedures, making observations, collecting data, controlling variables, and establishing relationships based on evidence and logical argument.

State Goal 12: Have a working knowledge of the fundamental concepts and principles of the life, physical, and earth/space sciences and their connections.

Late Elementary:

- CAS E—Analyze natural cycles, interactions, and patterns in the earth's land, water, and atmospheric systems.

Middle School:

- CAS E—Analyze the properties, functions, and formation of the earth's component features.

State Goal 13: Have a working knowledge of the relationships among science, technology, and society in historical and contemporary contexts.

Late Elementary:

- CAS C—Describe the historical roles of people and societies in the development of current scientific knowledge.

Middle School:

- CAS C—Recognize international contributions of scientists, including male and female persons from diverse cultures and persons with disabilities.

**Activity: Excavation Extravaganza
English Language Arts**

State Goal 1: Read with understanding and fluency.

Late Elementary:

- CAS A—Apply strategic reading behaviors to examine, construct, and extend the meaning of a wide variety of texts to be informed, to perform a task, and for literary experience.
- CAS B—Use a wide variety of word analysis strategies to construct meaning from unfamiliar texts.
- CAS C—Make and support inferences when reading nonfiction text, relating structure, organization, and content to the textual purpose.

Middle School:

- CAS A—Adjust strategies and reading rates according to the nature and purpose of a text to be informed, to perform a task, and for literary experience.
- CAS B—Uses semantic and syntactic cues to construct meaning from texts.
- CAS D—Analyze and evaluate information from expository texts, including public and functional documents.

State Goal 3: Write to communicate for a variety of purposes.

Late Elementary:

- CAS B—Write in a manner that reflects focus, organization, and coherence, using a variety of supporting evidence and elaborative detail.

Middle School:

- CAS B—Write with focus, organization, coherence, and unity in relation to purpose and audience, using a variety of supporting evidence and elaborative detail.

State 4: Listen and speak effectively in a variety of situations.

Late Elementary:

- CAS A—Listen and respond critically to gain knowledge from spoken messages and formal presentations.

Middle School:

- CAS A—Listen and respond analytically and critically to gain knowledge from formal, informal, and media/viewed settings.

State Goal 5: Use the language arts for inquiry and research to acquire, organize, analyze, evaluate, and communicate information.

Late Elementary:

- CAS A—Gather, organize, and integrate information from a variety of print and non-print sources to answer questions and solve problems related to investigation and research.

Middle School:

- Conduct research, individually and cooperatively, analyzing and applying the acquired information to produce presentations.

Mathematics

State Goal 7: Estimate, make, and use measurements of objects, quantities, and relationships and determine acceptable levels of accuracy.

Late Elementary:

- CAS A—Use appropriate units (customary and metric), tools, scales, and formulas to measure distance, area, capacity, temperature, and weight/mass of objects with whole numbers, fractions, and decimals.

Middle School:

- CAS A—Select and use appropriate units of measure to solve problems involving distance, rate capacity, weight/mass, perimeter, area, volume, time, temperature, and angles to the degree of accuracy required by particular situation.

State Goal 10: Collect, organize, and analyze data using statistical methods to predict results and interpret uncertainty and change in practical applications.

Late Elementary:

- CAS B—Draw conclusions and evaluate arguments based on data analysis and data displays (tables, charts, graphs), verifying reasoning.
- Formulate questions of interest and select ways to systematically collect, organize, and describe data appropriate to the questions.
- CAS D—Determine the probability of events when there are equally likely outcomes.

Middle School:

- CAS B—Formulate a hypothesis, define the population, collect and analyze data, draw conclusions, and communicate results.
- CAS C—Compare and make predictions based on theoretical probability and relative frequency.

Science

State Goal 11: *Have a working knowledge of the processes of scientific inquiry and technological design to investigate questions, conduct experiments, and solve problems.*

Late Elementary:

- CAS A—Identify problems and derive solutions to demonstrate an understanding of the processes of scientific investigation.
- CAS B—Design and safely conduct scientific investigations to answer questions and test the validity of predictions“ making observations, describing procedures, organizing data, drawing reasonable conclusions, and interpreting results.

Middle School:

- CAS A—Analyze data, draw conclusions based on evidence, and report results accurately in a variety of formats.
- CAS B—Demonstrate understanding of scientific processes and apply them to experiments: stating a purpose, developing a hypothesis, designing procedures, making observations, collecting data, controlling variables, and establishing relationships based on evidence and logical argument.

State Goal 12: *Have a working knowledge of the fundamental concepts and principles of the life, physical, and earth/space sciences and their connections.*

Late Elementary:

- CAS E—Analyze natural cycles, interactions, and patterns in the earth’s land, water, and atmospheric systems.

Middle School:

- CAS E—Analyze the properties, functions, and formation of the earth’s component features.

State Goal 13: *Have a working knowledge of the relationships among science, technology, and society in historical and contemporary contexts.*

Late Elementary:

- CAS A—Investigate and present ways in which science and technology have changed the tools, careers, resource use, and productivity of society over the centuries.
- CAS C—Describe the historical roles of people and societies in the development of current scientific knowledge.

Middle School:

- CAS A—Evaluate implications of technology for societies, vocations, economies, and the environment including trade-offs, intended benefits, unintended consequences, and constraints.
- CAS C—Recognize international contributions of scientists, including male and female persons from diverse cultures and persons with disabilities.

Activity: Fossil Facelift

English Language Arts

State Goal 1: *Read with understanding and fluency.*

Late Elementary:

- CAS A—Apply strategic reading behaviors to examine, construct, and extend the meaning of a wide variety of texts to be informed, to perform a task, and for literary experience.
- CAS B—Use a wide variety of word analysis strategies to construct meaning from unfamiliar texts.
- CAS C—Make and support inferences when reading nonfiction text, relating structure, organization, and content to the textual purpose.

Middle School:

- CAS A—Adjust strategies and reading rates according to the nature and purpose of a text to be informed, to perform a task, and for literary experience.
- CAS B—Uses semantic and syntactic cues to construct meaning from texts.
- CAS D—Analyze and evaluate information from expository texts, including public and functional documents.

State Goal 3: *Write to communicate for a variety of purposes.*

Late Elementary:

- CAS B—Write in a manner that reflects focus, organization, and coherence, using a variety of supporting evidence and elaborative detail.

Middle School:

- CAS B—Write with focus, organization, coherence, and unity in relation to purpose and audience, using a variety of supporting evidence and elaborative detail.

State 4: *Listen and speak effectively in a variety of situations.*

Late Elementary:

- CAS A—Listen and respond critically to gain knowledge from spoken messages and formal presentations.

Middle School:

- CAS A—Listen and respond analytically and critically to gain knowledge from formal, informal, and media/viewed settings.

State Goal 5: *Use the language arts for inquiry and research to acquire, organize, analyze, evaluate, and communicate information.*

Late Elementary:

- CAS A—Gather, organize, and integrate information from a variety of print and non-print sources to answer questions and solve problems related to investigation and research.

Middle School:

- Conduct research, individually and cooperatively, analyzing and applying the acquired information to produce presentations.

Mathematics

State Goal 7: Estimate, make, and use measurements of objects, quantities, and relationships and determine acceptable levels of accuracy.

Late Elementary:

- CAS A—Use appropriate units (customary and metric), tools, scales, and formulas to measure distance, area, capacity, temperature, and weight/mass of objects with whole numbers, fractions, and decimals.

Middle School:

- CAS A—Select and use appropriate units of measure to solve problems involving distance, rate capacity, weight/mass, perimeter, area, volume, time, temperature, and angles to the degree of accuracy required by particular situation.

Science

State Goal 11: Have a working knowledge of the processes of scientific inquiry and technological design to investigate questions, conduct experiments, and solve problems.

Late Elementary:

- CAS A—Identify problems and derive solutions to demonstrate an understanding of the processes of scientific investigation.
- CAS B—Design and safety conduct scientific investigations to answer questions and test the validity of predictions” making observations, describing procedures, organizing data, drawing reasonable conclusions, and interpreting results.

Middle School:

- CAS A—Analyze data, draw conclusions based on evidence, and report results accurately in a variety of formats.
- CAS B—Demonstrate understanding of scientific processes and apply them to experiments: stating a purpose, developing a hypothesis, designing procedures, making observations, collecting data, controlling variables, and establishing relationships based on evidence and logical argument.
- CAS C—Know and apply the concepts, principles, and processes of technological design.

State Goal 13: Have a working knowledge of the relationships among science, technology, and society in historical and contemporary contexts.

Late Elementary:

- CAS C—Describe the historical roles of people and societies in the development of current scientific knowledge.

Middle School:

- CAS C—Recognize international contributions of scientists, including male and female persons from diverse cultures and persons with disabilities.

Activity: How can Sue be in more than one place?

English Language Arts

State Goal 1: Read with understanding and fluency.

Late Elementary:

- CAS A—Apply strategic reading behaviors to examine, construct, and extend the meaning of a wide variety of texts to be informed, to perform a task, and for literary experience.
- CAS B—Use a wide variety of word analysis strategies to construct meaning from unfamiliar texts.
- CAS C—Make and support inferences when reading nonfiction text, relating structure, organization, and content to the textual purpose.

Middle School:

- CAS A—Adjust strategies and reading rates according to the nature and purpose of a text to be informed, to perform a task, and for literary experience.
- CAS B—Uses semantic and syntactic cues to construct meaning from texts.
- CAS D—Analyze and evaluate information from expository texts, including public and functional documents.

State Goal 3: Write to communicate for a variety of purposes.

Late Elementary:

- CAS B—Write in a manner that reflects focus, organization, and coherence, using a variety of supporting evidence and elaborative detail.

Middle School:

- CAS B—Write with focus, organization, coherence, and unity in relation to purpose and audience, using a variety of supporting evidence and elaborative detail.

State 4: Listen and speak effectively in a variety of situations.

Late Elementary:

- CAS A—Listen and respond critically to gain knowledge from spoken messages and formal presentations.

Middle School:

- CAS A—Listen and respond analytically and critically to gain knowledge from formal, informal, and media/viewed settings.

State Goal 5: Use the language arts for inquiry and research to acquire, organize, analyze, evaluate, and communicate information.

Late Elementary:

- CAS A—Gather, organize, and integrate information from a variety of print and non-print sources to answer questions and solve problems related to investigation and research.

Middle School:

- Conduct research, individually and cooperatively, analyzing and applying the acquired information to produce presentations.

Science

State Goal 11: Have a working knowledge of the processes of scientific inquiry and technological design to investigate questions, conduct experiments, and solve problems.

Late Elementary:

- CAS A—Identify problems and derive solutions to demonstrate an understanding of the processes of scientific investigation.
- CAS B—Design and safety conduct scientific investigations to answer questions and test the validity of predictions“ making observations, describing procedures, organizing data, drawing reasonable conclusions, and interpreting results.

Middle School:

- CAS A—Analyze data, draw conclusions based on evidence, and report results accurately in a variety of formats.
- CAS B—Demonstrate understanding of scientific processes and apply them to experiments: stating a purpose, developing a hypothesis, designing procedures, making observations, collecting data, controlling variables, and establishing relationships based on evidence and logical argument.
- CAS C—Know and apply the concepts, principles, and processes of technological design.

State Goal 13: Have a working knowledge of the relationships among science, technology, and society in historical and contemporary contexts.

Late Elementary:

- CAS C—Describe the historical roles of people and societies in the development of current scientific knowledge.

Middle School:

- CAS C—Recognize international contributions of scientists, including male and female persons from diverse cultures and persons with disabilities.

Activity: What are observation, theory, and speculation?

English Language Arts

State Goal 1: Read with understanding and fluency.

Late Elementary:

- CAS A—Apply strategic reading behaviors to examine, construct, and extend the meaning of a wide variety of texts to be informed, to perform a task, and for literary experience.
- CAS B—Use a wide variety of word analysis strategies to construct meaning from unfamiliar texts.
- CAS C—Make and support inferences when reading nonfiction text, relating structure, organization, and content to the textual purpose.

Middle School:

- CAS A—Adjust strategies and reading rates according to the nature and purpose of a text to be informed, to perform a task, and for literary experience.
- CAS B—Uses semantic and syntactic cues to construct meaning from texts.

- CAS D—Analyze and evaluate information from expository texts, including public and functional documents.

State Goal 3: Write to communicate for a variety of purposes.

Late Elementary:

- CAS B—Write in a manner that reflects focus, organization, and coherence, using a variety of supporting evidence and elaborative detail.

Middle School:

- CAS B—Write with focus, organization, coherence, and unity in relation to purpose and audience, using a variety of supporting evidence and elaborative detail.

State 4: Listen and speak effectively in a variety of situations.

Late Elementary:

- CAS A—Listen and respond critically to gain knowledge from spoken messages and formal presentations.

Middle School:

- CAS A—Listen and respond analytically and critically to gain knowledge from formal, informal, and media/viewed settings.

State Goal 5: Use the language arts for inquiry and research to acquire, organize, analyze, evaluate, and communicate information.

Late Elementary:

- CAS A—Gather, organize, and integrate information from a variety of print and non-print sources to answer questions and solve problems related to investigation and research.

Middle School:

- Conduct research, individually and cooperatively, analyzing and applying the acquired information to produce presentations.

Science

State Goal 11: Have a working knowledge of the processes of scientific inquiry and technological design to investigate questions, conduct experiments, and solve problems.

Late Elementary:

- CAS A—Identify problems and derive solutions to demonstrate an understanding of the processes of scientific investigation.
- CAS B—Design and safety conduct scientific investigations to answer questions and test the validity of predictions“ making observations, describing procedures, organizing data, drawing reasonable conclusions, and interpreting results.

Middle School:

- CAS A—Analyze data, draw conclusions based on evidence, and report results accurately in a variety of formats.
- CAS B—Demonstrate understanding of scientific processes and apply them to experiments: stating a purpose, developing a hypothesis, designing procedures, making observations, collecting data, controlling variables, and establishing relationships based on evidence and logical argument.

State Goal 12: Have a working knowledge of the fundamental concepts and principles of the life, physical, and earth/space sciences and their connections.

Late Elementary:

- CAS B—Compare and contrast organisms by their energy use, position in food webs, structures, and adaptations to different environments.

State Goal 13: Have a working knowledge of the relationships among science, technology, and society in historical and contemporary contexts.

Late Elementary:

- CAS A—Investigate and present ways in which science and technology have changed the tools, careers, resource use, and productivity of society over the centuries.
- CAS C—Describe the historical roles of people and societies in the development of current scientific knowledge.

Middle School:

- CAS A—Evaluate implications of technology for societies, vocations, economies, and the environment including trade-offs, intended benefits, unintended consequences, and constraints.
- CAS C—Recognize international contributions of scientists, including male and female persons from diverse cultures and persons with disabilities.

Activity: Tyrannosaurus Theories

English Language Arts

State Goal 1: Read with understanding and fluency.

Late Elementary:

- CAS A—Apply strategic reading behaviors to examine, construct, and extend the meaning of a wide variety of texts to be informed, to perform a task, and for literary experience.
- CAS B—Use a wide variety of word analysis strategies to construct meaning from unfamiliar texts.
- CAS C—Make and support inferences when reading nonfiction text, relating structure, organization, and content to the textual purpose.

Middle School:

- CAS A—Adjust strategies and reading rates according to the nature and purpose of a text to be informed, to perform a task, and for literary experience.
- CAS B—Uses semantic and syntactic cues to construct meaning from texts.
- CAS D—Analyze and evaluate information from expository texts, including public and functional documents.

State Goal 3: Write to communicate for a variety of purposes.

Late Elementary:

- CAS B—Write in a manner that reflects focus, organization, and coherence, using a variety of supporting evidence and elaborative detail.

Middle School:

- CAS B—Write with focus, organization, coherence, and unity in relation to purpose and audience, using a variety of supporting evidence and elaborative detail.

State 4: Listen and speak effectively in a variety of situations.

Late Elementary:

- CAS A—Listen and respond critically to gain knowledge from spoken messages and formal presentations.

Middle School:

- CAS A—Listen and respond analytically and critically to gain knowledge from formal, informal, and media/viewed settings.

State Goal 5: Use the language arts for inquiry and research to acquire, organize, analyze, evaluate, and communicate information.

Late Elementary:

- CAS A—Gather, organize, and integrate information from a variety of print and non-print sources to answer questions and solve problems related to investigation and research.

Middle School:

- Conduct research, individually and cooperatively, analyzing and applying the acquired information to produce presentations.

Mathematics

State Goal 10: Collect, organize, and analyze data using statistical methods to predict results and interpret uncertainty and change in practical applications.

Late Elementary:

- CAS D—Determine the probability of events when there are equally likely outcomes.

Middle School:

- CAS C—Compare and make predictions based on theoretical probability and relative frequency.

Science

State Goal 11: Have a working knowledge of the processes of scientific inquiry and technological design to investigate questions, conduct experiments, and solve problems.

Late Elementary:

- CAS A—identify problems and derive solutions to demonstrate an understanding of the processes of scientific investigation.
- CAS B—Design and safely conduct scientific investigations to answer questions and test the validity of predictions“ making observations, describing procedures, organizing data, drawing reasonable conclusions, and interpreting results.

Middle School:

- CAS A—Analyze data, draw conclusions based on evidence, and report results accurately in a variety of formats.
- CAS B—Demonstrate understanding of scientific processes and apply them to experiments: stating a purpose, developing a hypothesis, designing procedures, making observations, collecting data, controlling variables, and establishing relationships based on evidence and logical argument.

State Goal 12: Have a working knowledge of the fundamental concepts and principles of the life, physical, and earth/space sciences and their connections.

Late Elementary:

- CAS B—Compare and contrast organisms by their energy use, position in food webs, structures, and adaptations to different environments.

Activity: Anatomy 101

English Language Arts

State Goal 1: Read with understanding and fluency.

Late Elementary:

- CAS A—Apply strategic reading behaviors to examine, construct, and extend the meaning of a wide variety of texts to be informed, to perform a task, and for literary experience.
- CAS B—Use a wide variety of word analysis strategies to construct meaning from unfamiliar texts.
- CAS C—Make and support inferences when reading nonfiction text, relating structure, organization, and content to the textual purpose.

Middle School:

- CAS A—Adjust strategies and reading rates according to the nature and purpose of a text to be informed, to perform a task, and for literary experience.
- CAS B—Uses semantic and syntactic cues to construct meaning from texts.
- CAS D—Analyze and evaluate information from expository texts, including public and functional documents.

State Goal 3: Write to communicate for a variety of purposes.

Late Elementary:

- CAS B—Write in a manner that reflects focus, organization, and coherence, using a variety of supporting evidence and elaborative detail.

Middle School:

- CAS B—Write with focus, organization, coherence, and unity in relation to purpose and audience, using a variety of supporting evidence and elaborative detail.

State 4: Listen and speak effectively in a variety of situations.

Late Elementary:

- CAS A—Listen and respond critically to gain knowledge from spoken messages and formal presentations.

Middle School:

- CAS A—Listen and respond analytically and critically to gain knowledge from formal, informal, and media/viewed settings.

State Goal 5: Use the language arts for inquiry and research to acquire, organize, analyze, evaluate, and communicate information.

Late Elementary:

- CAS A—Gather, organize, and integrate information from a variety of print and non-print sources to answer questions and solve problems related to investigation and research.

Middle School:

- Conduct research, individually and cooperatively, analyzing and applying the acquired information to produce presentations.

Mathematics

State Goal 7: Estimate, make, and use measurements of objects, quantities, and relationships and determine acceptable levels of accuracy.

Late Elementary:

- CAS A—Use appropriate units (customary and metric), tools, scales, and formulas to measure distance, area, capacity, temperature, and weight/mass of objects with whole numbers, fractions, and decimals.

Middle School:

- CAS A—Select and use appropriate units of measure to solve problems involving distance, rate capacity, weight/mass, perimeter, area, volume, time, temperature, and angles to the degree of accuracy required by particular situation.

Science

State Goal 11: Have a working knowledge of the processes of scientific inquiry and technological design to investigate questions, conduct experiments, and solve problems.

Late Elementary:

- CAS A—identify problems and derive solutions to demonstrate an understanding of the processes of scientific investigation.
- CAS B—Design and safety conduct scientific investigations to answer questions and test the validity of predictions—making observations, describing procedures, organizing data, drawing reasonable conclusions, and interpreting results.

Middle School:

- CAS A—Analyze data, draw conclusions based on evidence, and report results accurately in a variety of formats.
- CAS B—Demonstrate understanding of scientific processes and apply them to experiments: stating a purpose, developing a hypothesis, designing procedures, making observations, collecting data, controlling variables, and establishing relationships based on evidence and logical argument.

Activity: Sue in the Flesh

English Language Arts

State Goal 1: Read with understanding and fluency.

Late Elementary:

- CAS A—Apply strategic reading behaviors to examine, construct, and extend the meaning of a wide variety of texts to be informed, to perform a task, and for literary experience.
- CAS B—Use a wide variety of word analysis strategies to construct meaning from unfamiliar texts.
- CAS C—Make and support inferences when reading nonfiction text, relating structure, organization, and content to the textual purpose.

Middle School:

- CAS A—Adjust strategies and reading rates according to the nature and purpose of a text to be informed, to perform a task, and for literary experience.
- CAS B—Uses semantic and syntactic cues to construct meaning from texts.
- CAS D—Analyze and evaluate information from expository texts, including public and functional documents.

State Goal 3: Write to communicate for a variety of purposes.

Late Elementary:

- CAS B—Write in a manner that reflects focus, organization, and coherence, using a variety of supporting evidence and elaborative detail.

Middle School:

- CAS B—Write with focus, organization, coherence, and unity in relation to purpose and audience, using a variety of supporting evidence and elaborative detail.

State 4: Listen and speak effectively in a variety of situations.

Late Elementary:

- CAS A—Listen and respond critically to gain knowledge from spoken messages and formal presentations.

Middle School:

- CAS A—Listen and respond analytically and critically to gain knowledge from formal, informal, and media/viewed settings.

State Goal 5: Use the language arts for inquiry and research to acquire, organize, analyze, evaluate, and communicate information.

Late Elementary:

- CAS A—Gather, organize, and integrate information from a variety of print and non-print sources to answer questions and solve problems related to investigation and research.

Middle School:

- Conduct research, individually and cooperatively, analyzing and applying the acquired information to produce presentations.

Science

State Goal 11: Have a working knowledge of the processes of scientific inquiry and technological design to investigate questions, conduct experiments, and solve problems.

Late Elementary:

- CAS A—Identify problems and derive solutions to demonstrate an understanding of the processes of scientific investigation.
- CAS B—Design and safely conduct scientific investigations to answer questions and test the validity of predictions“ making observations, describing procedures, organizing data, drawing reasonable conclusions, and interpreting results.

Middle School:

- CAS A—Analyze data, draw conclusions based on evidence, and report results accurately in a variety of formats.

- CAS B—Demonstrate understanding of scientific processes and apply them to experiments: stating a purpose, developing a hypothesis, designing procedures, making observations, collecting data, controlling variables, and establishing relationships based on evidence and logical argument.

Activity: Strand in Time English Language Arts

State Goal 3: Write to communicate for a variety of purposes.

Early Elementary:

- CAS B—Write with focus, coherence, and clarity.
- CAS C—Use stages of the writing process to develop short narrative, descriptive, expository, and persuasive texts that communicate in terms of audience, purpose, and context.

Late Elementary:

- CAS B—Write in a manner that reflects focus, organization, and coherence, using a variety of supporting evidence and elaborative detail.

Middle School:

- CAS B—Write with focus, organization, coherence, and unity in relation to purpose and audience, using a variety of supporting evidence and elaborative detail.

State 4: Listen and speak effectively in a variety of situations.

Early Elementary:

- CAS A—Listen and respond appropriately to oral messages.
- CAS C—Speak clearly and coherently in formal and informal settings.

Late Elementary:

- CAS A—Listen and respond critically to gain knowledge from spoken messages and formal presentations.

Middle School:

- CAS A—Listen and respond analytically and critically to gain knowledge from formal, informal, and media/viewed settings.

State Goal 5: Use the language arts for inquiry and research to acquire, organize, analyze, evaluate, and communicate information.

Early Elementary:

- CAS A—Conduct basic research using a variety of technological tools and research.

Late Elementary:

- CAS A—Gather, organize, and integrate information from a variety of print and non-print sources to answer questions and solve problems related to investigation and research.

Middle School:

- CAS A—Conduct research, individually and cooperatively, analyzing and applying the acquired information to produce presentations.

Mathematics

State Goal 7: Estimate, make, and use measurements of objects, quantities, and relationships and determine acceptable levels of accuracy.

Early Elementary:

- CAS C—Measure length, width, perimeter, area, liquid, volume, temperature, and mass of objects using customary and metric systems.

Late Elementary:

- CAS A—Use appropriate units (customary and metric), tools, scales, and formulas to measure distance, area, capacity, temperature, and weight/mass of objects with whole numbers, fractions, and decimals.

Middle School:

- CAS A—Select and use appropriate units of measure to solve problems involving distance, rate capacity, weight/mass, perimeter, area, volume, time, temperature, and angles to the degree of accuracy required by particular situation.

State Goal 10: Collect, organize, and analyze data using statistical methods to predict results and interpret uncertainty and change in practical applications.

Late Elementary:

- CAS B—Draw conclusions and evaluate arguments based on data analysis and data displays (tables, charts, graphs), verifying reasoning.

Middle School:

- CAS B—Formulate a hypothesis, define the population, collect and analyze data, draw conclusions, and communicate results.

Science

State Goal 11: Have a working knowledge of the processes of scientific inquiry and technological design to investigate questions, conduct experiments, and solve problems.

Late Elementary:

- CAS A—Identify problems and derive solutions to demonstrate an understanding of the processes of scientific investigation.
- CAS B—Design and safely conduct scientific investigations to answer questions and test the validity of predictions“ making observations, describing procedures, organizing data, drawing reasonable conclusions, and interpreting results.

Middle School:

- CAS A—Analyze data, draw conclusions based on evidence, and report results accurately in a variety of formats.
- CAS B—Demonstrate understanding of scientific processes and apply them to experiments: stating a purpose, developing a hypothesis, designing procedures, making observations, collecting data, controlling variables, and establishing relationships based on evidence and logical argument.

State Goal 12: Have a working knowledge of the fundamental concepts and principles of the life, physical, and earth/space sciences and their connections.

Early Elementary:

- CAS B—Understand effects of organisms on the environment and some features that help them survive and reproduce after a change in their environment.

Activity: Puzzling Pelvis

English Language Arts:

State 4: Listen and speak effectively in a variety of situations.

Early Elementary:

- CAS A—Listen and respond appropriately to oral messages.
- CAS C—Speak clearly and coherently in formal and informal settings.

Late Elementary:

- CAS A—Listen and respond critically to gain knowledge from spoken messages and formal presentations.

Middle School:

- CAS A—Listen and respond analytically and critically to gain knowledge from formal, informal, and media/viewed settings.

State Goal 5: Use the language arts for inquiry and research to acquire, organize, analyze, evaluate, and communicate information.

Early Elementary:

- CAS A—Conduct basic research using a variety of technological tools and research.

Late Elementary:

- CAS A—Gather, organize, and integrate information from a variety of print and non-print sources to answer questions and solve problems related to investigation and research.

Middle School:

- CAS A—Conduct research, individually and cooperatively, analyzing and applying the acquired information to produce presentations.

Science

State Goal 11: Have a working knowledge of the processes of scientific inquiry and technological design to investigate questions, conduct experiments, and solve problems.

Early Elementary:

- CAS A—Understand that science involves asking and answering questions and comparing experimental results to what is already known.
- CAS B—Design and conduct simple scientific investigations in which observations are made, data are gathered and organized, and reasonable conclusions are drawn.

Late Elementary:

- CAS A—Identify problems and derive solutions to demonstrate an understanding of the processes of scientific investigation.

- CAS B—Design and safety conduct scientific investigations to answer questions and test the validity of predictions” making observations, describing procedures, organizing data, drawing reasonable conclusions, and interpreting results.

Middle School:

- CAS A—Analyze data, draw conclusions based on evidence, and report results accurately in a variety of formats.
- CAS B—Demonstrate understanding of scientific processes and apply them to experiments: stating a purpose, developing a hypothesis, designing procedures, making observations, collecting data, controlling variables, and establishing relationships based on evidence and logical argument.

State Goal 12: Have a working knowledge of the fundamental concepts and principles of the life, physical, and earth/space sciences and their connections.

Early Elementary:

- CAS B—Understand effects of organisms on the environment and some features that help them survive and reproduce after a change in their environment.

Late Elementary:

- CAS B—Compare and contrast organisms by their energy use, position in food webs, structures, and adaptations to different environments.

Activity: What’s your hypothesis?

English Language Arts

State Goal 1: Read with understanding and fluency.

Late Elementary:

- CAS A—Apply strategic reading behaviors to examine, construct, and extend the meaning of a wide variety of texts to be informed, to perform a task, and for literary experience.
- CAS B—Use a wide variety of word analysis strategies to construct meaning from unfamiliar texts.
- CAS C—Make and support inferences when reading nonfiction text, relating structure, organization, and content to the textual purpose.

Middle School:

- CAS A—Adjust strategies and reading rates according to the nature and purpose of a text to be informed, to perform a task, and for literary experience.
- CAS B—Uses semantic and syntactic cues to construct meaning from texts.
- CAS D—Analyze and evaluate information from expository texts, including public and functional documents.

State Goal 3: Write to communicate for a variety of purposes.

Early Elementary:

- CAS B—Write with focus, coherence, and clarity.
- CAS C—Use stages of the writing process to develop short narrative, descriptive, expository, and persuasive texts that communicate in terms of audience, purpose, and context.

Late Elementary:

- CAS B—Write in a manner that reflects focus, organization, and coherence, using a variety of supporting evidence and elaborative detail.

Middle School:

- CAS B—Write with focus, organization, coherence, and unity in relation to purpose and audience, using a variety of supporting evidence and elaborative detail.

State 4: Listen and speak effectively in a variety of situations.

Early Elementary:

- CAS A—Listen and respond appropriately to oral messages.
- CAS C—Speak clearly and coherently in formal and informal settings.

Late Elementary:

- CAS A—Listen and respond critically to gain knowledge from spoken messages and formal presentations.

Middle School:

- CAS A—Listen and respond analytically and critically to gain knowledge from formal, informal, and media/viewed settings.

State Goal 5: Use the language arts for inquiry and research to acquire, organize, analyze, evaluate, and communicate information.

Early Elementary:

- CAS A—Conduct basic research using a variety of technological tools and research.

Late Elementary:

- CAS A—Gather, organize, and integrate information from a variety of print and non-print sources to answer questions and solve problems related to investigation and research.

Middle School:

- CAS A—Conduct research, individually and cooperatively, analyzing and applying the acquired information to produce presentations.

Science

State Goal 11: Have a working knowledge of the processes of scientific inquiry and technological design to investigate questions, conduct experiments, and solve problems.

Early Elementary:

- CAS A—Understand that science involves asking and answering questions and comparing experimental results to what is already known.
- CAS B—Design and conduct simple scientific investigations in which observations are made, data are gathered and organized, and reasonable conclusions are drawn.

Late Elementary:

- CAS A—identify problems and derive solutions to demonstrate an understanding of the processes of scientific investigation.
- CAS B—Design and safety conduct scientific investigations to answer questions and test the validity of predictions” making observations, describing procedures, organizing data, drawing reasonable conclusions, and interpreting results.

Middle School:

- CAS A—Analyze data, draw conclusions based on evidence, and report results accurately in a variety of formats.
- CAS B—Demonstrate understanding of scientific processes and apply them to experiments: stating a purpose, developing a hypothesis, designing procedures, making observations, collecting data, controlling variables, and establishing relationships based on evidence and logical argument.

State Goal 12: Have a working knowledge of the fundamental concepts and principles of the life, physical, and earth/space sciences and their connections.

Early Elementary:

- CAS B—Understand effects of organisms on the environment and some features that help them survive and reproduce after a change in their environment.

Late Elementary:

- CAS B—Compare and contrast organisms by their energy use, position in food webs, structures, and adaptations to different environments.

State Goal 13: Have a working knowledge of the relationships among science, technology, and society in historical and contemporary contexts.

Late Elementary:

- CAS C—Describe the historical roles of people and societies in the development of current scientific knowledge.

Middle School:

- CAS C—Recognize international contributions of scientists, including male and female persons from diverse cultures and persons with disabilities.