

Unearthing the Secrets of

SUE[®]



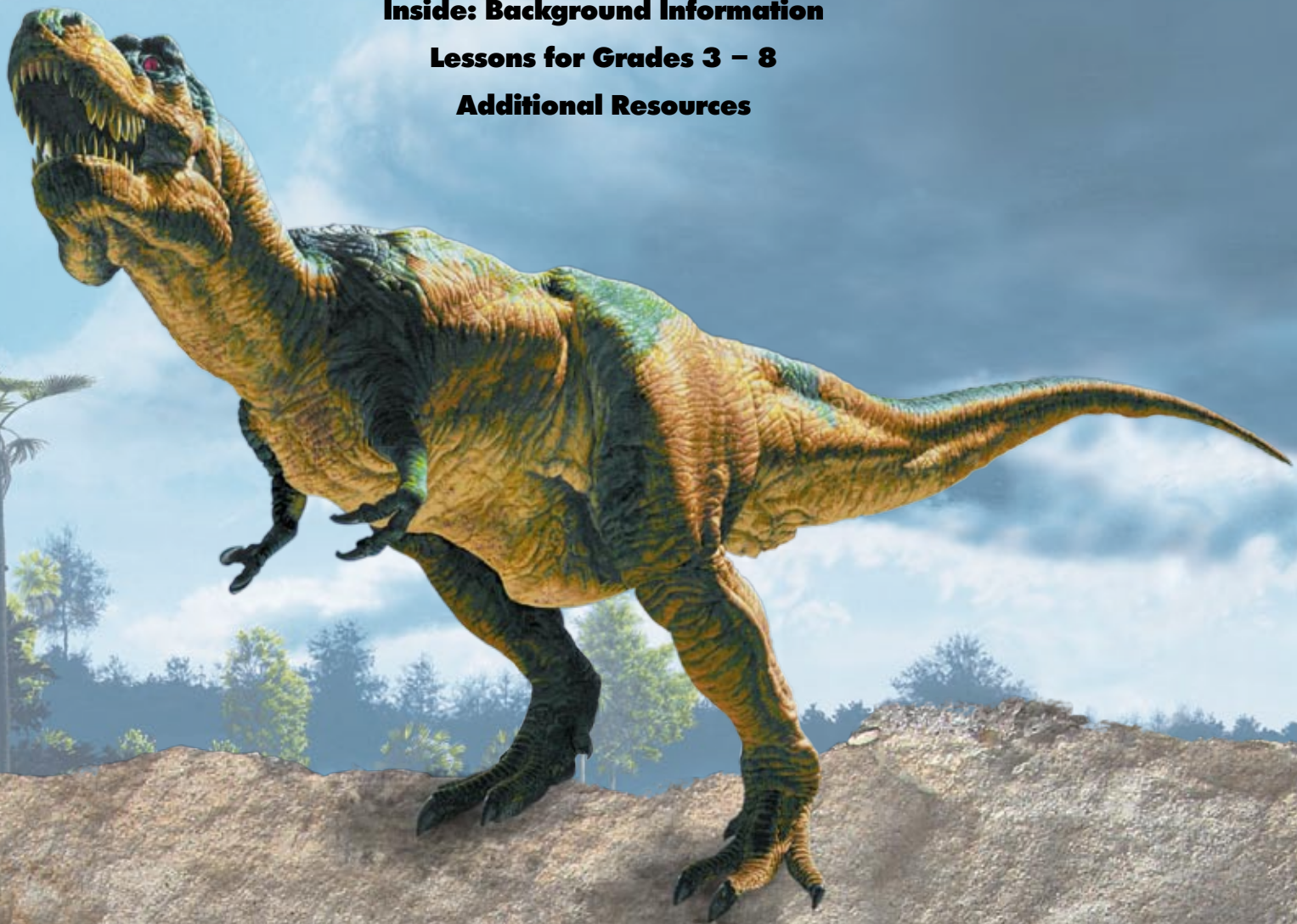
Educator Guide, Second Edition

fieldmuseum.org/SUE

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Unearthing the Secrets of SUE

No dinosaur in the world compares to SUE—the largest, most complete, and best preserved *Tyrannosaurus rex* ever discovered. In May 2000, the unveiling of her 67-million-year-old skeleton at The Field Museum made global headlines. Since then, more than 16 million visitors have marveled over Chicago’s prehistoric giant.

Using the story of SUE to captivate students’ imagination, the Unearthing the Secrets of *SUE* Educator Guide takes pre-k through eighth-grade students on an interactive exploration of SUE at The Field Museum and the scientific insights she’s providing about the world in which she lived. The lessons in this guide will engage students in the science of SUE 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;
- introducing students to careers in science by highlighting the wide professional expertise involved in the *SUE* project; and
- introducing students to the countless resources available to them through The Field Museum including field trips, and online research and interactive learning opportunities.



How to Use this Guide

- Detailed **Background Information** is provided to support educators in sharing the story of SUE with students. Use this information to prepare yourself and your students for learning about SUE.
- This guide presents a total of six **Lesson Plans**; three lessons per grade band: third through fifth, sixth through eighth. We encourage you to explore all lessons regardless of grade band given that they can be modified to best suit your instructional needs.
- Per grade band, we present two classroom lessons and one **Focused Field Trip** lesson to be conducted at The Field Museum. A focused field trip includes a pre-visit activity, an activity to do within the Museum, and a post-visit activity.
- The **Additional Resources** includes a list of related Field Museum resources, book list, Web sites, and a glossary that can be used to support and enhance your students’ educational experience.

Credits

Unearthing the Secret’s of *SUE*, Educator Guide, Second Edition was developed by The Field Museum Education and Exhibitions Departments.

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By counting the rings in a cross-section of dinosaur bone, scientists can learn many things about the organism’s life including its age at death. Students will examine bone rings and develop hypotheses about the life of *SUE* and other *Tyrannosaurids*.

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Students work in teams to conduct a fossil excavation from start to finish. Students make observations and a site map, hypothesize about where they think fossils are located, and record their discoveries during the excavation.

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Using Sue’s Anatomy Guide, students identify what kind of bones they excavated during the Excavation Extravaganza activity. Students then research similarities and differences between the bones they discovered and Sue’s bones, and learn about the relatedness of dinosaurs and birds.

Focused Field Trip: Science of SUE (pp. 42 – 44)

During a visit to The Field Museum’s *SUE* exhibition, students will study *SUE* in an attempt to answer current research questions being explored by Field Museum paleontologists.

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All About SUE

SUE's Significance

SUE is the largest, most complete, best preserved *Tyrannosaurus rex* in the world. But exactly what does that mean?

- **Size:** Bone for bone, SUE is bigger than any *T. rex* specimen yet discovered. She sets the record for overall length (40.5 feet) and skeletal weight (3,922 pounds). Out of the more than 30 *T. rex* skeletons discovered so far, SUE's beefy bones beat them all.
- **Preservation:** Virtually all parts of SUE's skeleton are preserved in great detail—even the surface of her bones. Scientists can actually see where muscles, tendons, and ligaments once attached. And not only are most of the bones undistorted from fossilization, but cross-sections of the bones show that even the cellular structure inside remains intact.
- **Completion:** SUE is more than 90% complete by bulk meaning scientists have recovered more of each of SUE's bones than any other *T. rex*. SUE's bone count includes many "firsts" found for *T. rex*, such as her furcula (wishbone), stapes (an ear bone), and almost all her gastralia (belly ribs.) Finding so many well-preserved bones for a single individual specimen gives scientists a rare chance to learn more about tyrannosaur anatomy and biology!

Vital Stats

- **Scientific name:** *Tyrannosaurus rex* (From the Greek and Latin for "tyrant lizard king")
- **Time:** Late Cretaceous Period 67 million years ago
- **Range:** Alberta (Canada), and Montana, Wyoming, Colorado, Utah, and North and South Dakota (U.S.A.)
- **Environment:** Warm, lush, and seasonally damp
- **Discovered:** August 12, 1990, on the Cheyenne River Sioux Indian Reservation near Faith, South Dakota, by fossil hunter Sue Hendrickson
- **Length:** 40.5 feet (12.9 meters)
- **Height at hips:** 13 feet (4.0 meters)
- **Estimated live weight:** more than 7 tons (6.4 metric tons)
- **Weight of skeleton:** 3,922 pounds (1.78 metric tons)
- **Weight of skull:** 600 pounds (272 kg)



FAQs

- Is SUE a boy or girl? While SUE is frequently referred to as a “she,” scientists don’t actually know her sex. At one point, scientists thought that the position of the first chevron (a little Y-shaped bone) along the bottom of SUE’s tail indicated that she was female, but this test turned out to be inaccurate.
- How old was SUE when she died? By counting the rings in SUE’s bones—like tree-ring dating—scientists have determined that SUE was 28 years old when she died. That’s near the maximum estimated age of around 30 years for *T. rex*. SUE is actually the oldest *T. rex* discovered so far!
- What did SUE eat? A carnivore, SUE was a predator (and perhaps a scavenger) of plant-eating dinosaurs. Big meat eaters are often both predator and scavenger in order to get enough food. But exactly what kind of dinosaurs did she eat? *T. rex* teeth have been found shed alongside the common herbivore Edmontosaurus, and some bones of Triceratops show scars left by *T. rex* teeth.
- How did SUE die? Scientists aren’t sure how SUE died—perhaps from old age, or perhaps from some disease that left no trace on her bones. One new theory attributes a jaw infection as a possibility. It may have caused her such pain that she couldn’t eat and eventually starved to death.
- Was SUE warm-blooded or cold-blooded? It’s still not known whether *T. rex* like SUE were warm-blooded (like birds) or cold-blooded (like crocodiles). However, recent studies of the growth rate in *Tyrannosaurids* show that they experienced rapid growth spurts in their teen years (14-18 yrs), a trait typical of warm-blooded animals.

SUE’s World

When fossil hunters discovered SUE in 1990, they also found a trove of other fossils. Together, these fossils represent many groups of plants and animals from the Cretaceous period—they provide scientists with a good picture of what lived with this famous dinosaur. From these fossils, scientists can tell that South Dakota 67 million years ago looked nothing like it does today. Far from being a dry flatland, the area was lush and damp. Great rivers ran through forested terrain to a sea that stretched across much of North America.

Huge hardwoods, conifers, ferns, palms, and cycads made up much of SUE’s habitat and provided food for the plant-eating dinosaurs that she hunted. Duck-billed *hadrosaurs*, bony-frilled *Triceratops*, and bipedal *Thescelosaurus* were her neighbors—and probably her meals.

Also found with SUE were fossils of water plants, fresh-water rays and sharks, other fishes, lizards, crocodylians, and amphibians, which tell us that she lived—and died—near a river. Clearly, SUE’s home state was a much wetter place than it is today.

About *T. rex*

Paleontologist Henry Fairfield Osborn coined the name *Tyrannosaurus rex* (“tyrant lizard king”) for a gigantic carnivore skeleton discovered by legendary dinosaur paleontologist Barnum Brown in 1902. Since then, more than 30 *T. rex* skeletons and a number of other scattered bones have been found, shedding light on the history of this species. *T. rex* is the largest and last of the 15 or so known *Tyrannosaurid* species. This lineage evolved from smaller feathered theropods that dominated the northern continents in the Late Cretaceous period (67-65 million years ago).

When tracing their family tree, *T. rex* falls between birds and their nearest relatives, the sickle-clawed dinosaurs and allosauroids—large carnivores of the Jurassic and Early Cretaceous periods. In particular, *T. rex* exhibits many bird-like traits such as brain structure, hollow bones, blood-cell structures, a wishbone, an upright stance, and a three-toed, forward-pointing foot.

Although no *T. rex* eggs have ever been found, it’s likely that females laid somewhere between 12–36 large and pointy eggs (assuming that their egg-laying pattern fell somewhere in between that of their nearest relatives.) It’s believed that their egg-laying strategy was closer to that of crocodiles, meaning they laid large numbers of proportionally smaller eggs rather than a few large eggs.

SUE's Journey: From Field to The Field Museum

SUE's Discovery

The story of SUE's discovery begins in the summer of 1990. At the time, fossil hunter Sue Hendrickson was working at a dig site near Faith, South Dakota, with a commercial fossil-collecting team from the Black Hills Institute. Early on the morning of August 12, the team discovered their truck had a flat tire, so they headed to town for repairs. Sue elected to stay behind and instead hiked out to an eroding bluff she'd noticed several days earlier. Within minutes, she spied some bone fragments that had rolled down the incline. Looking up, she spotted several vertebrae (backbones) and a large femur (thigh bone) sticking out of the bluff face. Sue immediately identified them as the bones of a large carnivorous dinosaur and suspected that they might be from a *Tyrannosaurus rex*. When the team returned, they confirmed her find and promptly named it "SUE" in her honor.

Excavating SUE's Bones

When Sue Hendrickson discovered her namesake's bones sticking out of an eroded bluff, all she could see were a few large vertebrae (backbones) and a femur (thigh bone). The team eagerly began excavating in the hopes of finding more. First, they chiseled away the rock surrounding each bone and reinforced the fossils with glue. Next, the team made a protective jacket for each piece by layering on cloth soaked in plaster. Finally, they packed the plaster-coated bones in crates for shipping. As the team worked, they recorded the position, orientation, and identity of each bone on a site map. They also excavated and noted findings of other animal and plant fossils found with SUE, which helped reveal more about her ancient environment.

It took six people 17 days to free SUE from her rocky grave. By that time, the team realized they had a unique find—a virtually complete, articulated skeleton of a huge *Tyrannosaurus rex*. The combination of her amazing state of preservation, completeness, and size quickly made SUE a hot scientific commodity. Eventually, the U.S. Government became involved because they feared SUE had been found on Federal land. During the argument over who owned SUE, the bones were safely locked away in storerooms at the South Dakota School of Mines and Technology. In the end, a judge decided that SUE was held in trust by the U.S. Government for the rancher on whose property the skeleton had been found. The rancher, in turn, decided to sell SUE at public auction.

Preparing SUE's Bones

After The Field Museum purchased SUE at auction for 8.6 million dollars in 1997, she came back to Chicago. But before her skeleton could be placed on display, each of her 200 or more bones had to be prepared by a team of skilled technicians. First, the museum built the glass-enclosed McDonald's Fossil Preparation Laboratory—a state-of-the-art facility for cleaning and restoring SUE's bones. Here, visitors could watch preparators at work and witness SUE's gradual emersion from stone.

Next, paleontologists painstakingly removed each fossilized bone from its rocky matrix using an air scribe (a mini jackhammer). The bones were then cleaned with an air abrader and other tools like those used by dentists. Any broken bones were carefully glued back together. In total, it took Field Museum scientists more than 30,000 hours to prepare SUE's bones—that equates to one person working 15 years, full-time! Just the skull alone required 3,500 hours of work.

But after two years of hard labor removing three tons of rock and debris, preparators estimated that they were to recover more than 90% of SUE's bones.

Modeling SUE's Bones

After cleaning and repairing SUE's bones, preparators made exact copies of every single bone—five complete models of SUE in total. Why make replicas when you own the real thing? For study and display. Some of the copies remain at the museum, unassembled, so that visiting scientists can study SUE's bones up close. Others have been assembled into full skeletons and now travel around the world, giving everyone a chance to see this amazing *T. rex*.

But SUE's existing bones weren't the only parts that were copied. Her missing bones needed to be fabricated, too. Scientists at The Field Museum called other museums that have *T. rex* skeletons, hoping to find models for SUE's absent bits. But in her case, these "off-the-shelf" bones weren't big enough. Instead, substitute pieces were created in three ways. A few of SUE's bones were cast twice, and then the extra casts were modified in size and shape to fit the bill. Some bones that were present on one side but missing on the other were matched using computer generated modeling. And just a couple of bones—like the missing tip of SUE's tail—were sculpted from scratch by an artist.

Exhibiting SUE's Skeleton

Once Field Museum preparators had cleaned and repaired her bones, SUE was ready to be assembled. But to hold such a fragile yet heavy skeleton, a special mount needed to be made. So The Field Museum called in Phil Fraley Productions, experts in mounting large, fossilized specimens. Older methods of mounting heavy fossils involved destroying portions of the bones by drilling holes through them for iron supports. But Fraley's state-of-the-art steel armature safely cradles the bones, mirroring the original placement of muscles, tendons, and ligaments. The end effect is a more lifelike posture for SUE and greater security for her skeleton.

One of the most unique aspects of the mount is that every bone sits like a precious jewel in its own "ring setting." This allows each individual bone to be removed for scientific study and then put back in place. To design, engineer, and build the mount took 24 people around 24,000 work-hours—and then the team had to dismantle everything, pack it, ship it to the museum, and reassemble SUE on site. But it was worth all the work when SUE, poised for action, made her dramatic debut on May 17, 2000.

Science of SUE

SUE's Senses

Like all *T. rex*, SUE's diet was made up of meat—mostly plant-eating dinosaurs. A creature her size probably had to both hunt and scavenge to get enough to eat. Her skeleton tells us that her body was built for her lifestyle.



- **Eyesight:** On SUE's skull, her eye sockets faced forward, as do those of most other predators and scavengers, including humans. This means SUE had good depth perception and could tell how far away her next meal was.
- **Hearing:** The internal structure of SUE's ear was much like yours. In fact, *T. rex* had the best hearing of all theropod dinosaurs and could probably easily hear potential prey approaching.
- **Sense of smell:** Based on the length of SUE's snout and the size of the odor-detecting region in her brain, scientists think that SUE had a keen sense of smell. She would've had no problem sniffing out carrion or potential prey, but likely hunted by sight more than scent.
- **Bite Force:** SUE's serrated teeth were perfect for biting through flesh and bone. Their backwardly curved shape also prevented struggling meals from escaping. Estimates of a *T. rex*'s bite force places it higher than the largest living alligator or crocodile.
- **Speed & Agility:** As a rule in nature, extremely large animals like elephants are not as fast as mid-sized animals like horses or antelope. That's why scientists think that SUE couldn't run fast. Her top speed was probably only 15 mph—still faster than most of her prey.

SUE's Age

How old was SUE, and how did she grow to be so big? In 2004, Field Museum paleontologist Dr. Peter Makovicky worked to answer this question with collaborators from Florida State University and elsewhere. First, they took slices from the bones of several individuals belonging to four North American *Tyrannosaurid* species. (SUE's bones were just one of seven *T. rex* specimens they sampled.) Then, the team examined these slices beneath a microscope to count the rings in their bones. Like tree stumps, dinosaur bones (and those of most living reptiles) are marked by rings indicating annual growth.

Next, they charted the growth rate of all four species—and discovered some surprising facts. Members of the *T. rex* group experienced huge growth spurts during their teen years (12-18 yrs). They grew at a rate of 4.5 pounds per day, versus only 0.6-1.1 pounds for the individuals from the other three *Tyrannosaurid* species. For comparison, during our fastest growth period (when we're teenagers), we humans grow only about half an ounce a day. No wonder *T. rex* like SUE towered over most other dinosaurs! Bone-ring counting also revealed SUE's true age—she was 28 when she died—and probably close to the upper limit of a *T. rex*'s estimated life span. Out of the 12 *T. rex* specimens that have since had their ages analyzed, SUE remains the oldest.

SUE's Brain

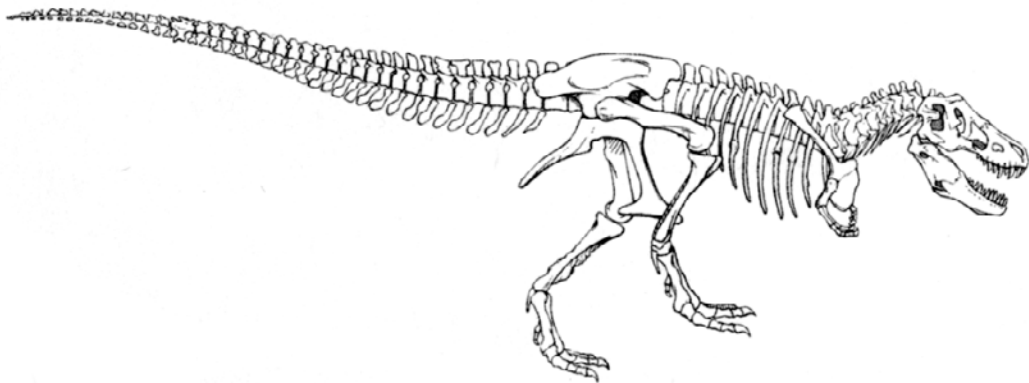
In 1998, SUE's skull traveled to the Boeing Company's Rocketdyne Labs in California where it spent 500 hours inside one of the world's most powerful CT scanners. Field Museum researcher Dr. Chris Brochu then analyzed the images to map out the regions of SUE's brain. The CT scans revealed that, although her brain didn't fossilize, the braincase surrounding it is remarkably well preserved—in size, the brain cavity was just big enough to hold about a pint of liquid. SUE's brain itself was around a foot (30.5 cm) long and shaped like a knobby sweet potato or a head of broccoli.

Interestingly, one of the larger regions of SUE's brain was devoted to detecting and processing smells. This makes sense for a creature that probably spent its life sniffing out prey and/or carrion to eat. Also, the CT scan showed scientists that *T. rex* shared certain details of brain anatomy with birds—the placement of the midbrain above the hindbrain, and the expansion of the forebrain. All of these details create a better picture of the *T. rex* family tree.

SUE's Body

Dr. Peter Makovicky, of The Field Museum, is currently working to create 3D models and animations of SUE that can help us better visualize how *T. rex* may have looked and moved. The first step in building a virtual SUE required cutting-edge laser imaging technologies. Forensic specialists from the Chicago Police Department completed laser scans of SUE's mounted skeleton using an instrument that creates digital 3D models of crimes scenes.

Next, for a complete digital model of almost all of SUE's bones, staff at Loyola University Medical Center scanned research casts of SUE in a high-resolution CT x-ray machine. Ford Motor Company in Michigan and Joe Lichko of Cubic Vision then scanned the parts that were too big to fit in Loyola's machine. With Dr. Makovicky's input, the various scans are now being combined in an exhaustive process by the team of Ralph Chapman, Linda Deck, and Art Andersen, to generate an extremely detailed digital copy of SUE's skeleton. Over the coming months, they'll use this model to flesh out SUE's bones, measure her size, estimate her weight, and refine models that could tell us how fast and agile she may have been.



Grades 3 – 5

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 Earth.

Grade Level

Grades 3 – 5

Time Required

45 – 60 minutes

National Science Education Standards

- Content Standard D – Earth and Space Science: Properties of Earth materials

Illinois State Learning Standards

- 1.C. Comprehend a broad range of reading materials.
- 4.A. Listen effectively in formal and informal situations.
- 4.B. Speak effectively using language appropriate to the situation and audience.
- 5.A. Locate, organize, and use information from various sources to answer questions, solve problems and communicate ideas.
- 7.A. Measure and compare quantities using appropriate units, instruments and methods.
- 10.A. Organize, describe and make predictions from existing data.
- 11.A. Know and apply the concepts, principles and processes of scientific inquiry.
- 12.E. Know and apply concepts that describe the features and processes of the Earth and its resources.

Vocabulary

Timeline

Fossil record

Extinct

Materials

- Investigation Sheet
- Rulers
- String 30 feet long
- Tape
- Books about prehistoric life on Earth
- Colored pencils, markers, or crayons
- Construction paper or drawing paper

Advance Preparation

Gather materials. Make copies of the Investigation Sheet, 1 per student or small group.

Procedure

1. Assess student understanding: What is a timeline? What can you learn by studying a timeline?
Explain that students will illustrate the history of life on Earth by creating a timeline. Begin by attaching the string to a wall in your school.
2. Pass out the Investigation Sheet. Explain that the data on the sheet represents years of scientific research on the fossil record. Scientists continue to study the fossil record to understand what life was like on Earth in the past. Review the Earth history events listed on the Investigation Sheet. Assign each student or small group an event on the timeline.
3. Have students measure and post the events along the timeline. Then have students research their assigned event using appropriate non-fiction secondary sources.
4. Students should create illustrations of their assigned event. Have students attach their illustrations to the string in the proper location. Ask students to share their findings. What was interesting? How was life different on Earth at that time than today? Have students ask questions of each other.
5. Briefly introduce the story of SUE the *Tyrannosaurus rex* by visiting fieldmuseum.org/sue or reading passages from the background information.
6. Ask students: Where would SUE be located on the timeline? Why? What is your reasoning? (Hint: *Tyrannosaurus rex* lived on Earth between 67-65 million years ago). Have students add SUE to the timeline.

Investigation Sheet

Event	Years Ago	Distance on Time line
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	230 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

Activity Description

During a visit to The Field Museum's *Evolving Planet* and *SUE* exhibitions, students will gather data from the fossil record to expand the timeline created during the Strand of Time lesson. Afterwards, students will discuss the difference between primary and secondary sources.

Grade Level

Grades 3 – 5

Time Required

Field trip to The Field Museum: 1/2 day – 1 day, Post-Visit Activity: 40 minutes

National Science Education Standards

- Content Standard A – Science as Inquiry: Abilities to do scientific inquiry
- Content Standard A – Science as Inquiry: Understandings about scientific inquiry
- Content Standard D – Earth and Space Science: Properties of Earth materials

Illinois State Learning Standards

- 4.A. Listen effectively in formal and informal situations.
- 4.B. Speak effectively using language appropriate to the situation and audience.
- 5.A. Locate, organize, and use information from various sources to answer questions, solve problems and communicate ideas.
- 10.A. Organize, describe and make predictions from existing data.
- 11.A. Know and apply the concepts, principles and processes of scientific inquiry.
- 12.E. Know and apply concepts that describe the features and processes of the Earth and its resources.

Vocabulary

Fossil record

Materials

- Journals or notebooks
- Pencils
- Colored pencils, markers, or crayons
- Construction paper or drawing paper
- Tape

Advance Preparation

Pre-register for a visit to The Field Museum at least 14 days prior to your desired field trip date. To place your reservation, go to fieldmuseum.org/fieldtrip. General admission includes access to the *Evolving Planet* and *SUE* exhibitions. Visit fieldmuseum.org/education for more information. **Be sure to complete A Strand of Time lesson prior to your field trip.**

Procedure

Field Trip Activity

1. At The Field Museum, go to the *Evolving Planet* exhibition. The exhibition is organized chronologically, starting with the formation of Earth and continuing through present day.
2. Have students collect data for their assigned timeline event (continuation of A Strand of Time lesson). To help students find their assigned event, direct students' attention to the large circle time-markers on the floor of the exhibition.
3. Have students examine fossils and accompanying exhibition images to learn more about their assigned event. If digital cameras are available, encourage students to take pictures as well. Students should record data in their journals through sketching and writing.
4. Visit the *SUE* exhibition, have students collect data on SUE to add to the timeline. Students should also develop and write down questions they have about SUE that could be researched later in the classroom.

Back in the classroom:

1. Have students add the data collected at the Museum to the timeline. Encourage students to share their findings. What did you learn by studying the fossil record and Museum exhibition? How were the resources at the Museum different from those used in the Strand of Time lesson (fossils = primary sources, books/illustrations = secondary sources)? Were there differences between the data you collected and the books you examined?
2. If you were a scientist, what sources of information would you use to answer your questions? As a class, create a list of sources that are appropriate for scientists to use in their research.

Activity Description

By counting the rings in a cross-section of dinosaur bone, scientists can learn many things about the organism's life including its age at death. Students will learn about this process, make observations of bone rings and develop hypotheses about the lives of *Tyrannosaurids*.

Grade Level

Grades 3–5

Time Required

45 minutes

National Science Education Standards

- Content Standard A – Science as Inquiry: Abilities necessary to do inquiry
- Content Standard A – Science as Inquiry: Understandings about scientific inquiry
- Content Standard C – Life Science: Life cycles 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

Illinois State Learning Standards

- 1.A. Apply word analysis and vocabulary skills to comprehend selections.
- 1.B. Apply reading strategies to improve understanding and fluency.
- 4.A. Listen effectively in formal and informal situations
- 7.A. Measure and compare quantities using appropriate units, instruments and methods.
- 11.A. Know and apply the concepts, principles and processes of scientific inquiry.
- 13.A. Know and apply the accepted practices of science.

Vocabulary

Cross-section

Growth rings

Microscope

Materials

- Cross-section of tree or branch
- Microscopes or magnifying glasses
- Scientist Story
- Investigation Sheet
- Observation Sheet
- Metric rulers
- Pencils

Advance Preparation

Gather materials. To obtain tree or branch cross-sections, cut a branch from your backyard or school grounds. Make copies: Scientist Story, 1 per small group or student; Observation Sheet, 1 per student; Investigation Sheet, 1 per small group or student.

Procedure

1. Have students make observations of the tree cross-sections using magnifying glasses and/or microscopes. Ask students: What can you learn by examining a cross-section of a tree? Explain that for each year of growth, students should be able to count a ring in the cross-section.
2. Have students count the rings of a tree cross-section and share the age of the tree. Have students share other observations (distance between rings, color, etc.). What do you think these differences tell us about the growth of the tree? (availability of resources, illness, etc.)
3. Explain that paleontologists use a similar strategy to understand the growth and life history of some dinosaurs. Read the Scientist Story featuring a paleontologist applying this method of investigation, Dr. Peter Makovicky from The Field Museum.
4. Pass out the Investigation Sheets and Observation Sheets. Explain that the images show different cross-sections of *Tyrannosaurid* bones. Have students make careful observations of the cross-sections and write them on their Observation Sheets. Have students share their observations. What is similar between the cross-sections? What is different? What do you think the differences tell us?
5. Have students complete the Observation Sheets, including measurements. Share and discuss students' measurements. Identify differences in students' findings. Why were there differences (availability of resources, illness, etc.)? Relate discussion to understanding the process of inquiry and the practices of science.

Scientist Story



Dr. Peter J. Makovicky, Paleontologist

Hi, my name is **Dr. Pete Makovicky**. I'm a paleontologist at The Field Museum. A big part of my job is studying prehistoric life on Earth like plants and dinosaurs. When I discover a fossil, I observe it carefully. Often times, my observations lead me to ask a lot of questions about life on Earth. One of the questions I would like to answer is: How old was SUE when she died and how did she grow to be so big?

To answer my question, I counted bone rings with a team of scientists. Have you ever counted the rings of a tree stump to find out how old it was? You can do the same thing with dinosaur bone. First, we took slices from bones of several North American *tyrannosaurid* species, including SUE. *Tyrannosaurids* are a group of bipedal (walked on two legs) carnivorous (meat-eating) dinosaurs with lots of large teeth. Then, the team examined these slices using a microscope to count the rings in their bones. Like tree stumps, each ring in a dinosaur bone equals one year of growth. How old are you? If you were a dinosaur, your bones would have the same number of rings as your age.

By looking at the slices of dinosaur bones, we discovered some surprising facts! We learned that members of the *T. rex* group had huge growth spurts as teenagers. They grew at a rate of 4.5 pounds per day! Other *tyrannosaurid* species did not grow as fast. Bone ring counting also helped us learn how old SUE was when she died. SUE was 28 years old when she died! You can learn a lot more about dinosaurs by studying the rings in their bones. Give it a try!



In the field!

Investigation Sheet

Image 1:

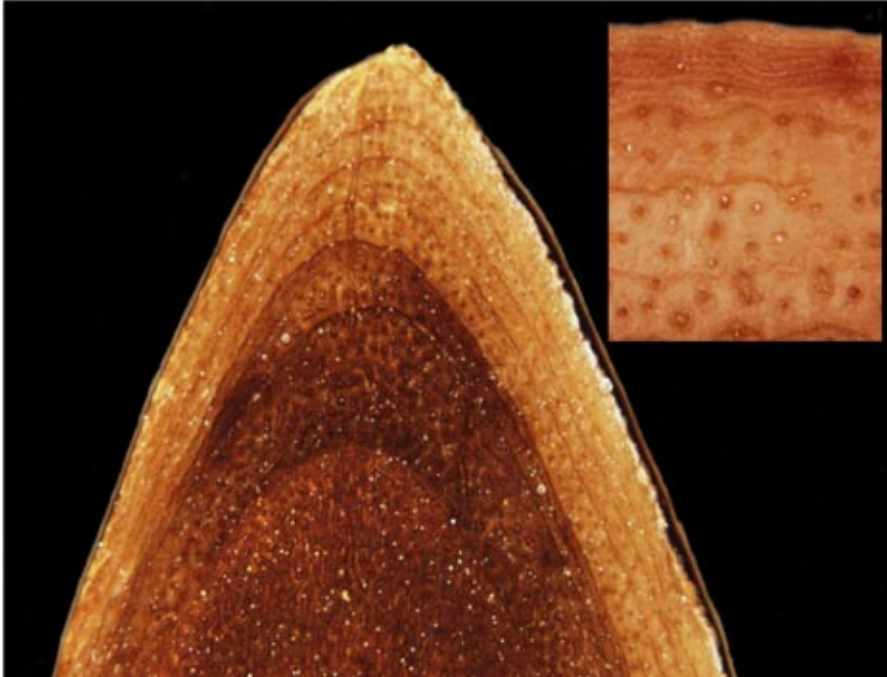
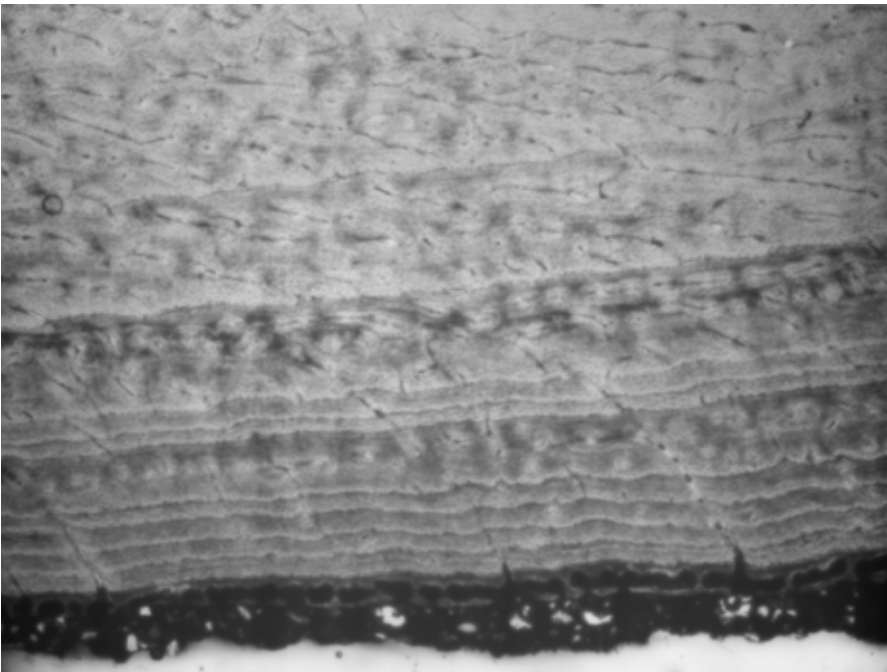


Image 2:



Observation Sheet

Image Number _____

1. What are your observations?

2. What do you find interesting about the image?

3. Label each ring on the cross-section. How many rings are there?

4. What is the distance between each ring?

Ring _____ to ring _____ = _____ mm

Ring _____ to ring _____ = _____ mm

Ring _____ to ring _____ = _____ mm

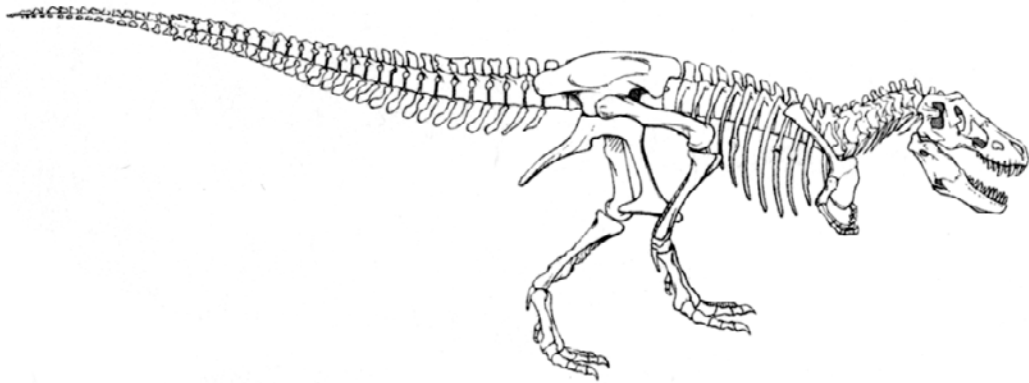
Ring _____ to ring _____ = _____ mm

Ring _____ to ring _____ = _____ mm

Ring _____ to ring _____ = _____ mm

Ring _____ to ring _____ = _____ mm

Ring _____ to ring _____ = _____ mm



Grades 6 - 8

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.

Grade Level

Grades 6 – 8

Time Required

Advance Preparation: 2+ days, Student Investigation: Day 1: 30 minutes, Day 2: 60 minutes

National Science Education Standards

- Content Standard A – Science as Inquiry: Abilities necessary to do scientific inquiry
- Content Standard A – Science as Inquiry: Understandings about scientific inquiry
- Content Standard C – Life Science: Diversity and adaptations of organisms
- Content Standard D – Earth and Space Science: Earth’s history

Illinois State Learning Standards

- 1.C. Comprehend a broad range of reading materials.
- 3.C. Compose ideas in writing to accomplish a variety of purposes.
- 4.A. Listen effectively in formal and informal situations.
- 7.A. Measure and compare quantities using appropriate units, instruments and methods.
- 7.B. Estimate measurements and determine acceptable levels of accuracy.
- 11.A. Know and apply the concepts, principles and processes of scientific inquiry.
- 12.E. Know and apply concepts that describe the features and processes of the Earth and its resources.

Vocabulary

Excavate

Quadrangle

Fossil

Materials

- Prepared excavation site (see Advance Preparation Parts A and B)
- 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)

Advance Preparation Part A (1 day)

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.
- Heat source (stove top)
- Oven
- A large metal container
- Foil
- Baking tray
- Dishwasher detergent
- Bleach
- Water

Procedure

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 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 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 bones 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 or balsa wood skeleton puzzle pieces. 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.

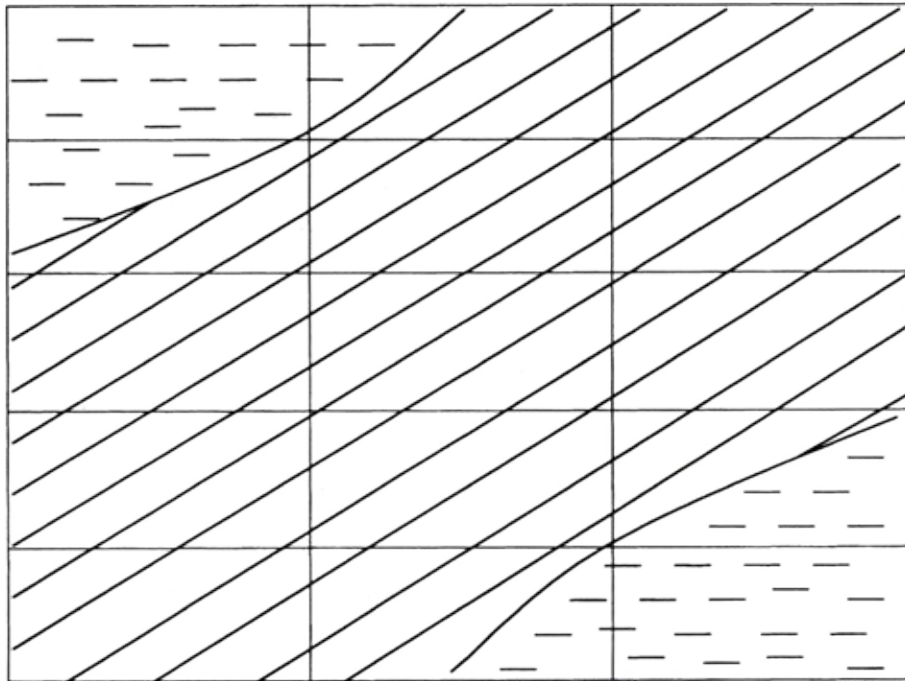
Advance Preparation Part B (1 day)

Materials

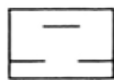
- Excavation Site Diagram
- 15 half-gallon milk or juice containers – You need at least one container for every team of 2–3 students. You may want to ask students to bring these containers from home a week before the lab.
- Soil – A large bag of potting soil should be sufficient to fill the Stratum A containers (see diagram) 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) 3/4 full.
- Plaster of paris
- Large bucket

Procedure

1. Prepare the containers (milk jugs). 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 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. Make copies of Background Information, Site Map, Bone Map, Bone Data Sheet, and Investigation Sheet for each student; assemble as Field Notebook.



Key:



Stratum A – does not contain fossils



Stratum B – does contain fossils

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.

Procedure

Day 1 (30 minutes)

1. Assign students to teams of 3-5 students.
2. Have students observe the site and respond to question 1 on the Investigation Sheet in their Field Notebooks.
3. Have students record their observations on the Investigation Sheet (questions 2-3). As students make observations, prompt with questions: What does the exposed rock look like? Is the rock the same everywhere? Do you see any fossils?
4. Once finished recording observations, have students draw a Site Map of the excavation site. Follow the directions from the Site Map page in the Field Notebook.
5. Based on their observations and site map, ask students: Where do you think you will find fossils? Students should record their answers on the Investigation Sheet (questions 4-6). This may be assigned as homework.

Day 2 (60 minutes)

1. Have teams select a quadrangle to excavate; each team should excavate a different quadrangle. Ask students to read the instructions on the Bone Map and Bone Data Sheet before starting the excavation.
2. Student teams should carefully remove matrix by using the tools available. Warn students to keep an eye out for fossils. Do not rush. Rushing could damage the bone.
3. When teams discover a fossil, they should follow the instructions in the Bone Map and Bone Data Sheet. Students should record information about each bone.
4. When students are finished excavating their site, clean up. Have students save the bones excavated. Give each team a plastic bag in which to store fossils. Label the bag with the quadrangle name.
5. Have students respond to questions 7-9 on the Investigation Data Sheet.
6. If desired, have students work as a class to construct a large class Bone Map.

Field Notebook

Background Information

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 Hills 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.

Student Investigation

You will work in teams to conduct a fossil excavation from start to finish. After making observations and a site map, you will hypothesize about where you think fossils are located. Based on your team’s hypothesis, you will choose a location and start hunting for fossils. Upon discovery of bones, you will create a bone map and record detailed information about your find as you remove the fossil.

Field Notebook

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.

Field Notebook

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.

Field Notebook

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

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?

Activity Description

Using SUE's Anatomy Guide, students identify what kind of bones (i.e. vertebrae, pelvis, femur, etc.) they excavated during the Excavation Extravaganza activity. Students then research similarities and differences between the bones they discovered and SUE's bones, and develop theories about SUE based on research about birds and crocodiles.

Grade Level

Grades 6 – 8

Time Required

Day 1: 45 minutes, Day 2: 60 minutes

National Science Education Standards

- Content Standard A – Science as Inquiry: Abilities necessary to do scientific inquiry
- 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
- Content Standard G – History and Nature of Science: Nature of science

Illinois State Learning Standards

- 1.A. Apply word analysis and vocabulary skills to comprehend selections.
- 1.C. Comprehend a broad range of reading materials.
- 3.C. Compose ideas in writing to accomplish a variety of purposes.
- 4.A. Listen effectively in formal and informal situations.
- 11.A. Know and apply the concepts, principles and processes of scientific inquiry.
- 12.E. Know and apply concepts that describe the features and processes of the Earth and its resources.

Vocabulary

Anatomy

Theory

Materials

- Bones from Excavation Extravaganza
- Bone Sheet from Excavation Extravaganza
- Background Information
- SUE's Anatomy Guide
- Investigation Sheet
- Glue
- Paper
- Pencils
- Non-fiction books about birds
- Non-fiction books about crocodiles
- Computer lab with internet access (for research)

Advance Preparation

Gather materials. Make copies of the Background Information, Sue's Anatomy Guide, and Investigation Sheet for each student. Plan on making 4 Investigation Sheets per student.

Procedure

Day 1 (45 minutes)

1. Have students read the Background Information and SUE's Anatomy Guide.
2. Then, have students compare the bones and Bone Sheet from the Excavation Extravaganza lesson with the bones in SUE's Anatomy Guide.
3. Ask students to formulate hypotheses about the kind of bones that were uncovered and record hypotheses on the Investigation Sheet.
4. Have students share the hypotheses as a whole group. Share with students that the bones excavated were from a chicken. Ask: Why do you think the bones are so similar?

Day 2 (60 minutes)

1. Explain that scientists theorize that birds and crocodiles are dinosaurs' closest modern relatives. Ask students: Based on your observations and hypotheses about the chicken bones and SUE's bones, would you agree with this scientific theory? Why or why not?
2. Drawing from the theory that birds and crocodiles are dinosaurs' closest modern relatives, scientists are able to use observations of these animals to formulate hypotheses about *T. rex*. Have students use this technique to formulate their own hypotheses 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?
3. Working with a partner, have students conduct research to answer one of the above questions. For example, after doing some research students might learn that neither chickens nor crocodiles nurse their young. 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 form a hypothesis. Did SUE nurse her young? Probably not! 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 form a hypothesis. If the answer is yes for one and no for the other, then guess what? You do not have enough information to form a hypothesis.
4. In their research, have students include the following information: what was learned, what sources were used (citations), their hypothesis based on research, what fossil evidence supports their theory.
5. Upon completion, have students share their research with classmates. Encourage students to ask questions, share research that supports classmates' hypotheses and/or challenge hypotheses that aren't supported by their initial research.

Background Information

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.



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 (backbones)

There are four different types of bones that make up the vertebral column: neck, back, sacrum, 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.



Back

These vertebrae are typically larger than neck vertebrae.

The back 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.



SUE's Anatomy Guide

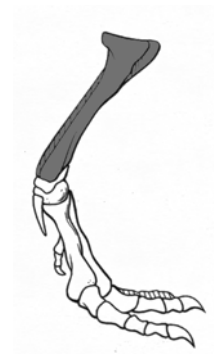
Femur (thigh bone)

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.



Activity Description

During a visit to The Field Museum's *SUE* exhibition, students will study SUE in an attempt to answer current research questions Field Museum paleontologists are grappling with. They will then learn how advances in technology have led to a deeper understanding of SUE's life.

Grade Level

Grades 6 – 8

Time Required

Pre-Visit Activity: 60 minutes

Field trip to The Field Museum: 1/2 day – 1 day

Post-Visit Activity: 60 minutes

National Science Education Standards

- Content Standard A – Science as Inquiry: Abilities to do scientific inquiry
- Content Standard A – Science as Inquiry: Understandings about scientific inquiry
- Content Standard C – Life Science: Structure and function in living systems
- Content Standard D – Earth and Space Science: Earth's history
- Content Standard F – Science in Personal and Social Perspectives: Science and technology in society

Illinois State Learning Standards

- 3.C. Communicate ideas in writing to accomplish a variety of purposes.
- 4.A. Listen effectively in formal and informal situations.
- 4.B. Speak effectively using language appropriate to the situation and audience.
- 5.A. Locate, organize, and use information from various sources to answer questions, solve problems and communicate ideas.
- 5.C. Apply acquired information, concepts and ideas to communicate in a variety of formats.
- 11.A. Know and apply the concepts, principles and processes of scientific inquiry.
- 12.A. Know and apply concepts that explain how living things function, adapt and change.

Vocabulary

CT scan

3D digital imaging

Materials

- Journals or notebooks
- Pencils
- Computer or computer lab with internet access
- Library or non-fiction books for research

Advance Preparation

Pre-register for a visit to The Field Museum at least 14 days prior to your desired field trip date. To place your reservation, go to fieldmuseum.org/fieldtrip. General admission includes access to the *SUE* exhibition. Visit fieldmuseum.org/education for more information. We highly recommend completing Excavation Extravaganza and Anatomy 101 prior to your visit.

Procedure

Pre-Visit Activity

1. Explain that scientists continue to ask and answer questions about SUE's life, such as:
 - a. How did SUE's senses help her as a dominant predator (eyesight, hearing, sense of smell)?
 - b. Was SUE a healthy individual? What illnesses and injuries did she sustain during her life?
2. Assign students to research teams (3-5 students per team). Have each team select one of the aforementioned questions to research in the classroom and at the Museum.
3. Ask each team to propose a hypothesis and method(s) by which the question could be answered. Allow teams time to develop their research plan. Ensure that each team discusses what data could be collected at the Museum; when examining SUE's skeleton, what would they look for? Encourage students to include methods practiced during the previous lesson (using research on birds and crocodiles to support their hypotheses).
4. Have students begin in-classroom research.
Make sure students do not visit The Field Museum's Web site until after their field trip.

Field Trip Activity

1. At The Field Museum, go to the *SUE* exhibition. Have student teams collect data to answer their assigned research question by carefully observing SUE and recording relevant data (sketches and writing).
2. The Dinosaur Hall in *Evolving Planet* exhibition and the *World of Birds* may also be used to collect data if teams have determined it a necessary method.
3. After spending time with SUE, visit SUE's skull on the upper level of the Museum. Have students read about how CT scanning helped scientists to learn about her brain.

Back in the classroom:

1. Have students write up their findings and report their research to the class. Encourage students to include their research question, hypothesis, research methods, findings, and conclusion.
2. Discuss any challenges they faced in conducting their research. What was limiting? What technologies might have been useful in answering their research question? Explain that scientists continue to learn about SUE's life because of advances in technology.
3. Have students visit fieldmuseum.org/sue or read the Background Information provided in this guide to learn what technologies are being used to answer current research questions.

Related Field Museum Exhibitions

Continue your exploration of SUE by visiting a related permanent exhibition during a subsequent visit or extended field trip:

Evolving Planet (Upper Level)

Evolving Planet takes visitors on an awe-inspiring journey through 4 billion years of life on Earth, from single-celled organisms to towering dinosaurs and our extended human family.

World of Birds (Main Level)

Around 65 million years ago, a mass extinction wiped out at least half of all species, including all dinosaurs. Except birds! Come face to beak with the dinosaurs of today in the *World of Birds* and

North American Birds exhibitions, and see how they live in Bird Habitats.

Mammals of Asia (Main Level)

Extinction is not just a thing of the past. Explore *Mammals of Asia* to see mammals that are on the brink of extinction today, such as the leopard (*Panthera pardus*).

On-line Resources

The Field Museum: *Crown Family PlayLab* exhibition

fieldmuseum.org/playlab/

The Field Museum: *Dinosaurs: Ancient Fossils, New Discoveries* exhibition

fieldmuseum.org/dinosaurs/

The Field Museum: *Evolving Planet* exhibition

fieldmuseum.org/evolvingplanet/

The Field Museum: *Expeditions @ The Field* (Dr. Peter Makovicky)

fieldmuseum.org/expeditions/pete_expedition/petehome.html

The American Museum of Natural History

amnh.org/exhibitions/dinosaurs/?src=e_f

Dinosaur Articles

dinosauria.com

The Franklin Institute Earthforce:

fi.edu/earth/earth.html

Geological Time

pubs.usgs.gov/gip/geotime/contents.html

Paleomap Project

scotese.com

OLOGY: PaleontOLOGY

ology.amnh.org/paleontology

National Geographic: Dinosaur Eggs

nationalgeographic.com/dinoeggs/museum/intro/museum.html

Books for Teachers

- Barrett, P. (1999). *National Geographic Dinosaurs*. Washington, D.C.: The National Geographic Society.
- Currie, Philip J. and Padian, Kevin. (1997). *Encyclopedia of Dinosaurs*. New York: Academic Press.
- Curry Rogers, Kristina A. and Jeffrey A. Wilson. (2005). *The Sauropods: Evolution and Paleobiology*. Berkeley: University of California Press.
- Farlow, J. O., and Brett-Surman, M. K. (1997). *The Complete Dinosaur*. Indianapolis, Indiana University Press.
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- Scotchmoor, J., Breithaupt, B., Springer, D. and A. Fiorillo. 2002. *Dinosaurs: The Science behind the Stories*. American Geological Institute, Alexandria, VA.
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Books for Students

- Aliki. (1988). *Digging Up Dinosaurs*. New York: HarperCollins.
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- Arnold, C. (1990). *Dinosaurs Down Under*. New York: Clarion Books.
- Blackstone, Stella and Beaton, Clara. (2005). *I Dreamt I Was a Dinosaur*. MA: Barefoot Books.
- Cole, Joanna. (1994). *The Magic School Bus: In the Time of the Dinosaurs*. New York: Scholastic.
- Dingus, Lowell. (1994). *What Color Is That Dinosaur?* Brookfield, Conn.: Millbrook Press.
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Glossary

- 3D Laser Scan:** A technology that uses laser light to generate a three-dimensional image or map of a structure or object.
- Anatomy:** The structure of an organism, or of any of its parts.
- Ancestor:** A species that gave rise to another species through evolutionary change.
- Body Fossil:** The direct physical remains of ancient plants and animals such as shells, bones, teeth, wood, seeds, and leaves.
- CT Scan:** A technology that uses X-ray to generate a three-dimensional view of an object and its internal structure.
- Dinosaur:** A group of reptiles that walked with their legs directly beneath their body and characterized by a hole in the hip socket. Dinosaurs first evolved during the Triassic Period, some 230 million years ago. Most went extinct during a mass extinction 65 million years ago; birds are the only dinosaurs that survived.
- Excavate:** To expose or unearth.
- Extinction:** The disappearance of a species or a population.
- Field Jacket:** A cast made of plaster, burlap, aluminum foil, and tissue paper that surrounds a fossil and matrix for protection.
- Fossil:** The remains or traces of organisms that were once alive. Fossils can include bones, trackways, skin impressions, etc.

- Fossil Record:** Evidence of the history of life on Earth preserved in sedimentary rocks. The record includes not only body fossils, but also trace fossils, and also captures information on interactions between organisms and the environment (e.g. shifts in oxygen levels with the rise of photosynthetic organisms).
- Growth Rings:** A trace in a bone (or tree limb) marking the end of growth in one season or year, and forming a boundary to the growth record for the following year.
- Hypothesis:** An explanation of one or more phenomena in nature that can be tested by observations, experiments, or both.
- Jurassic Period:** The second and middle period of the Mesozoic Era, ranging from about 210 to 141 million years ago. Birds first evolved during the Jurassic.
- Mass Extinction:** When a large proportion of species go extinct within a relatively short time (several million years) across much of the world. There have been at least six mass extinctions in the four billion years since life began.
- Matrix:** A very thin layer of rock that cover a fossil.
- Mesozoic Era:** The period of Earth's history from about 250 to 65 million years ago; often known as "The Age of Dinosaurs."
- Microscope:** An optical instrument having a magnifying lens or a combination of lenses for studying objects too small to be seen or too small to be seen distinctly and in detail by the unaided eye.
- Natural Selection:** The driving mechanism of evolutionary change: organisms that are better adapted to their environment are more likely to survive.

- Paleontologist:** A scientist who studies fossils to better understand life in prehistoric times.
- Paleontology:** The science that investigates extinct organisms and the history of life on Earth.
- Preparator:** A person who prepares a specimen for scientific research or exhibition.
- Preparation:** The process of preparing a specimen for scientific research or exhibition. Fossils are often encased in the rock that preserved them and need to be cleaned or exposed for study and exhibit.
- Quadrangle:** A four-sided polygon. Squares and rectangles are both quadrangles with a right angle at each corner.
- Science:** A way of knowing about the natural world based on observations and experiments that can be confirmed or disproved by other scientists using accepted scientific techniques.
- Theory:** An explanation of some phenomenon of the natural world that is well supported by the evidence at hand.
- Timeline:** A linear representation of important events in the order in which they occurred.
- Trace Fossil:** The indirect evidence of ancient animal activity (behavior) including tracks, trails, burrows, borings, egg nests, gizzard stones (gastroliths), and dung (coprolites).
- Triassic Period:** The first period of the Mesozoic Era, ranging from about 250 to 210 million years ago. Dinosaurs, crocodiles, lizards, turtles, and mammals all first evolved during the Triassic Period.