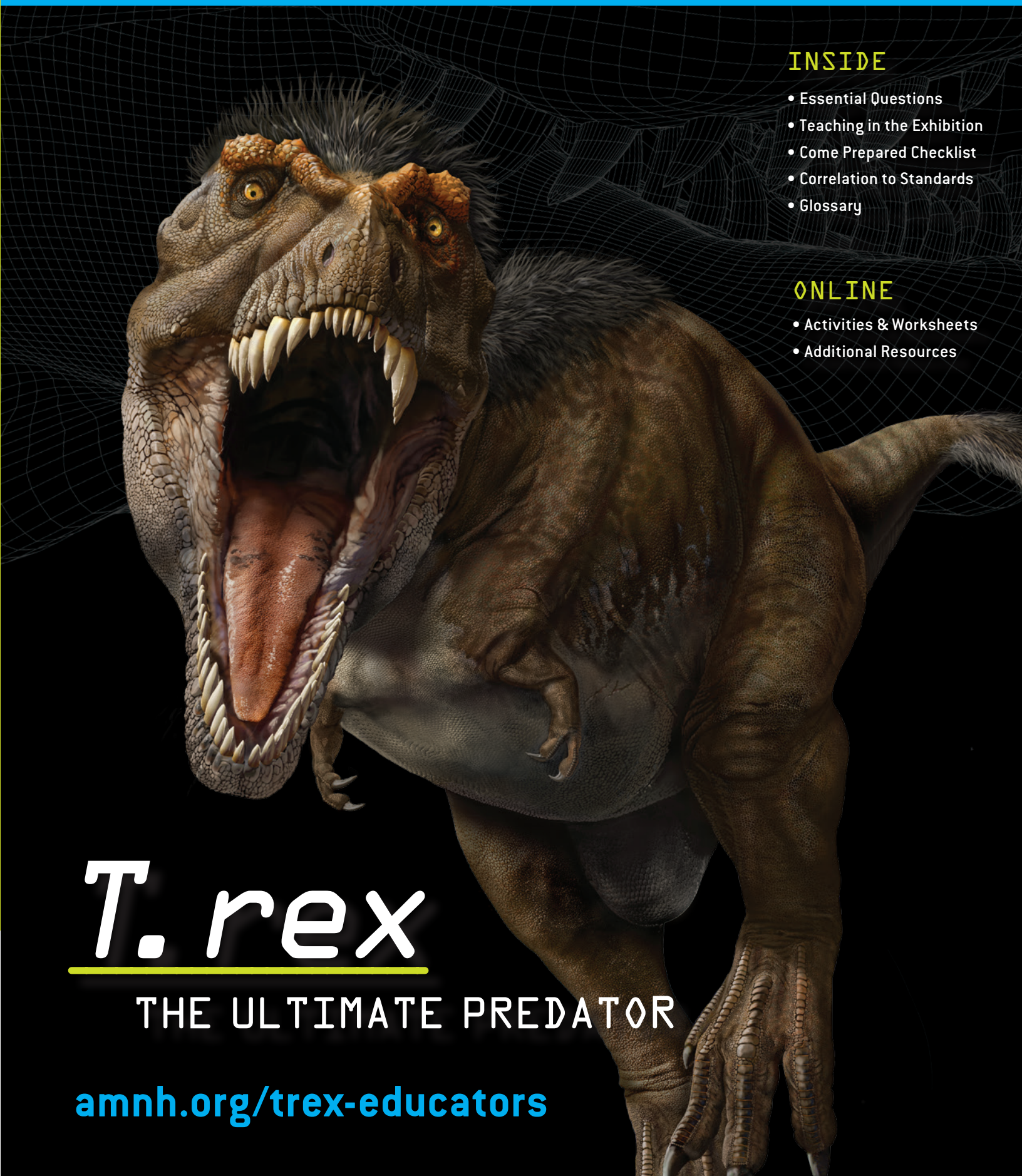
150 YEARS | AMERICAN MUSEUM OF NATURAL HISTORY

EDUCATOR'S GUIDE



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T. rex

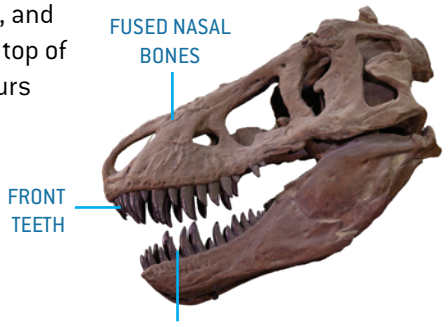
THE ULTIMATE PREDATOR

amnh.org/trex-educators

ESSENTIAL Questions

What is *T. rex*?

Tyrannosaurus rex, or *T. rex*, whose name means "tyrant lizard king," is a species of **theropod dinosaur** that lived in North America at the end of the Cretaceous Period, between about 68 and 66 million years before present (mybp). *T. rex* is the only species within the **genus** *Tyrannosaurus*, which is part of the superfamily Tyrannosauroidea. All members of this diverse group are broadly referred to as tyrannosaurs. Tyrannosaurs all share several distinctive traits that together identify them as a group, including front teeth that are D-shaped in cross section with a flat back edge, serrated teeth like a saw blade, and fused nasal bones on top of the snout. Tyrannosaurs comprise dozens of different kinds of animals living between about 167 and 66 mybp, distributed across five continents.



How many kinds of animals are in the *T. rex* evolutionary tree?

Although the massive *Tyrannosaurus rex*—with its huge head, tiny arms, and powerful jaws—is the most famous, it is not a typical tyrannosaur. **Fossils** reveal that early tyrannosaurs were quick and small, some only wolf size, with arms long enough to grasp prey or pull food into their mouths. Fossilized feathers from different species of tyrannosaurs also suggest that tyrannosaurs had primitive feathers, perhaps for insulation, camouflage, species recognition, and/or display. Tyrannosaurs **evolved** for over 100 million years. The trend was toward larger size, with giants like *T. rex* evolving very late in the timeline. No evolutionary path is a straight line; the tyrannosaur evolutionary tree has many branches, resulting in species that look very different from one another living at the same time.

The earliest known tyrannosaur, *Proceratosaurus bradleyi*, which lived about 167 mybp, had a dramatic, thin crest for display. It was found on the Isle of Wight off the southern coast of England.

How did *T. rex* live and grow?

Every *T. rex* was once a helpless hatchling, most likely covered in fuzz like a duckling. More than half of the chicks probably died in their first year. But by age two, a *T. rex* was already as large as other predatory dinosaurs in its realm. It would not reach its full adult size until it was around 20 years old. Without an adult's vast bulk and strength, young *T. rex* occupied separate **ecological niches**. Juveniles and adults had different diets and probably lived in different habitats.

A juvenile's body resembled earlier, smaller tyrannosaurs in size, proportions, and other anatomical features. Bladelike teeth could cut flesh, but could not crush bone. Relatively long arms could snatch prey and long legs allowed it to move quickly. Scales and feathers probably covered much of the body for insulation, camouflage, species recognition, and/or display.

As it got older, *T. rex* grew quickly, reaching full size by its early twenties. A full-grown *T. rex* was about 13 meters (43 feet) long. It likely lost most of its feathers, probably retaining only a few for display (perhaps on its head, arms, and tail), and leaving the rest of its body covered in scales. Its head, legs, and body outgrew its arms, until *T. rex* was so heavy—about 5,500 to 8,000 kg (six to nine tons)—that it could no longer leap and run. Now its greatest assets were its massive skull and strong, deeply rooted, bone-crushing teeth, capable of producing a powerful bite without breaking.

How do we study tyrannosaurs?

In 1902, American Museum of Natural History **paleontologist** Barnum Brown made a spectacular discovery in Montana, U.S.A.: a fossil that would later be named *Tyrannosaurus rex*. Since then, paleontologists have continued to adapt new techniques to understand tyrannosaurs. To identify different species, they compare fossilized bones and teeth. To determine an animal's age, they count growth rings in bones. To understand the keen senses of *T. rex*, they use **CT scans** to produce virtual 3D models that are replicas of the animals' brains. To investigate what *T. rex* ate, they examine **coprolites**, or fossilized poop. These contain many tiny chunks of bones eroded by stomach acids, revealing that *T. rex* could pulverize and partially digest solid bone. With new discoveries every year, we are learning more and more about these and other extinct animals. Their lives may be long over, but their stories are just beginning to be told.

TEACHING in the Exhibition

INTRODUCTION

When we think of *Tyrannosaurus rex*, we tend to imagine a massive, ferocious predator, but every fearsome adult was once a small, helpless chick. Tyrannosaurs evolved for over 100 million years, with *T. rex* appearing in the last 2 million years. The opening section of the exhibition introduces the main themes.

1a. Model of *T. rex* hatchling and shadow of adult: Tell students that in this exhibition, they will learn how this little chick grew into a giant adult *T. rex*.

1b. "Uncovering an Icon" section: Students explore the century-old discovery of *T. rex* and our evolving understanding of this theropod, including its posture. Have students discuss what they already know about *T. rex* (e.g. representations from movies and toys) and what they expect to see in this exhibition.

Unearthing a *T. rex* skull, the AMNH 5027 specimen, in Hell Creek, Montana, 1908

MEET THE FAMILY

***T. rex* is the most famous member of its group, but it is not a typical tyrannosaur. This section explores the evolutionary tree of *T. rex* and showcases its smaller, faster relatives.**

2a. "Meet the Superfamily" wall: The tyrannosaur evolutionary tree contains many species. Have students find *T. rex* on the branching diagram and observe the diversity of sizes and proportions within the tyrannosaur group.

2b. Models of *Proceratosaurus*, *Dilong*, *Xiongguanlong*: Have students observe the models of three early relatives of *T. rex*. Emphasize that these are life-size models of animals that lived millions of years before *T. rex*. Have them observe and read about the many diverse features, such as crests and feathers, and compare and contrast these three species to one another.

Dilong paradoxus, which lived about 126 mybp in what is now northeastern China, had relatively long arms capable of seizing small prey. It may have been covered in primitive feathers, perhaps for insulation, camouflage, species recognition, and/or display.

2c. "Roaming the Globe" map and "*T. rex* Traits" wall: Students look at a world map to see where tyrannosaurs have been found. Next, they learn which traits *T. rex* shares with other tyrannosaurs, and which are distinctive to *T. rex*.

2d. "Survival Challenge" station: Students decide what they would do if they were a small tyrannosaur eating a carcass and a large tyrannosaur showed up to steal it.

2e. Magnetic board: On this wall, students construct a *T. rex* skeleton by piecing together body parts.

2f. Tail balance interactive: Students put different tails on a *T. rex* model to explore how this bipedal animal balances at its center of gravity, rather than being propped up by its tail.

GETTING BIG

An animal's size affects the way it survives and hunts. This section investigates how a young *T. rex* grew up to become a massive adult.

3a. Model of *T. rex* juvenile: Have students observe the models and read about their features and the accelerated growth of *T. rex*. Then they can examine an adult toe bone fossil and touch an adult femur fossil cast.

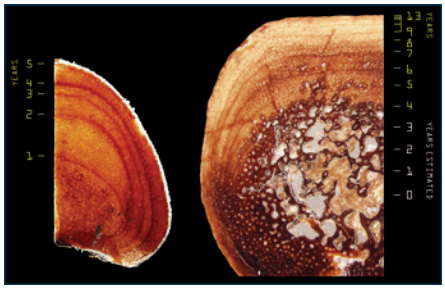
3b. "Survival Challenge" station: Students decide what they would do if they were a *T. rex* chick left alone in the nest.

3c. Growth rates interactive: Students push a button to compare the relative size and weight of *T. rex*, a smaller dinosaur, and a human at three different ages.

3d. *Tarbosaurus* juvenile skeleton and adult skull: Have students explore the changing hunting behavior and ecological niche of tyrannosaurs as they grow up.

3e. "Running vs. Walking" interactive: Students compare the movement of a young *T. rex* with an adult *T. rex*.

3f. Growth rings: Students see how scientists calculate a dinosaur's age by counting growth rings in fossilized bones.



Left: A cross section of a young dinosaur's bone still has its five early growth rings, indicating it was five years old. **Right:** A cross section of an older dinosaur's bone is missing its early growth rings; scientists calculated its age, about 13, by estimating the number of missing rings.

GETTING BAD

Fossil evidence shows that *T. rex* was a fearsome killer. This section examines the anatomical features that allowed this "tyrant lizard king" to dominate its competition.

4a. *T. rex* skeleton and shadow theater: In this multimedia projection, students watch a *T. rex* shadow come to life. They then watch it hunt prey and discover how its keen senses and unique physical traits made it an efficient killing machine. They watch it fight off an attack from another *T. rex* and see the scars that the fight left behind in its bones.

4b. Tooth, jaw, and claw fossils: Students observe and read about how adaptations such as huge, thick, deeply rooted teeth, frequent tooth replacement, and strong, bone-crushing jaws allowed *T. rex* to kill and eat its prey. They can also contemplate the puzzle of why an adult *T. rex* had such seemingly useless little arms.

More than half of each adult *T. rex* tooth was embedded deep in the jaws, helping it withstand the immense bending forces during a bite.

4c. "Hidden Clues" interactive: Students push a button to explore what fossils reveal about the musculature, behavior, and even past injuries of a *T. rex*. The highlighted bones correspond to those shown on the skeleton and in the shadow theater.

4d. "Survival Challenge" station: Students decide what they would do if they were a 4-year-old *T. rex* that encountered an armored dinosaur while hunting.

4e. "Room at the Top" section: Have students compare the skulls of several apex predators, including a lion, cheetah, leopard, *Tarbosaurus*, and *Alioramus*, to each other and to *T. rex*. Then have them read about how top predators that share an ecosystem avoid competing directly with one another.

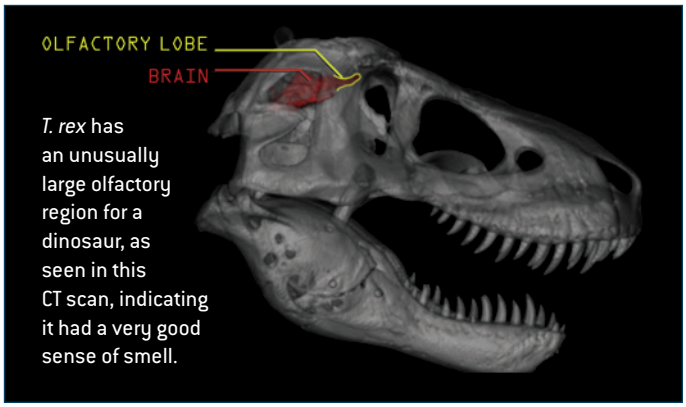
4f. Coprolite and bite marks: Students observe a cast of a coprolite and read about the evidence it provides for the bone-crushing power of *T. rex*. They can also examine photos of bones for evidence that *T. rex* ate members of its own species, as well as a cast of an *Edmontosaurus* fossil for evidence that *T. rex* was not just a scavenger, but also hunted live prey.

SENSITIVE SIDE

The study of living birds and other reptiles gives insight into *T. rex* behavior and biology. This section explores what paleontologists are discovering about the sensory abilities and social behavior of this powerful hunter.

5a. Models of *T. rex* adult and hatchlings: Tell students that this is a fleshed-out model of the *T. rex* skeleton in the "Getting Bad" section, and that they can explore the surrounding panels to see what new research reveals about this predator's keen vision, sense of smell, and hearing.

5b. Brain and senses section: Students observe a brain cast of a *T. rex* and explore what its size and shape reveal about this hunter's vision, hearing, and sense of smell.



5c. "Survival Challenge" station: Students decide what they would do if they were a hungry 20-year-old *T. rex* whose nose sensed a duck-bill dinosaur nearby.

5d. Headgear, scales, feathers, and colors section: Students explore the fossil evidence for *T. rex* feathers, which might have been used in mating displays, species recognition, insulation, and/or camouflage. In an interactive, students choose their own color scheme and featheration for a virtual *T. rex*.

5e. "Hear Me Roar" sound interactive: Students mix their own version of a *T. rex* roar by blending sounds of birds, crocodiles, and other living animals.

DON'T MISS!

Virtual Lab Touchscreen Table: Students analyze virtual fossils and investigate questions about them by applying data from CT scans and microphotography.

Interactive Projection Wall: Here students can experience *T. rex* in its Cretaceous environment.

Visit **amnh.org/trex-educators** for more resources!

COME PREPARED CHECKLIST

- ☐ **Plan your visit.** For information about reservations, visit **https://www.perotmuseum.org/education/**
- ☐ **Read the Essential Questions** to see how themes in the exhibition connect to your curriculum. Identify the key points that you'd like your students to learn.
- ☐ **Review the Teaching in the Exhibition section** for an advance look at what your class will encounter.
- ☐ **Download activities and student worksheets** at **amnh.org/trex-educators**. They are designed for use before, during, and after your visit.*Please note all maps in AMNH resources are of the exhibition at AMNH and do not reflect the layout at the Perot Museum.
- ☐ **Decide how your class will explore the exhibition:**
  - You and your chaperones can facilitate the visit using the Teaching in the Exhibition section.
  - Students can use the worksheets to explore on their own or in small groups.

CORRELATION TO STANDARDS

A Framework for K-12 Science Education

Science Practices • Asking questions • Developing and using models • Planning and carrying out investigations • Constructing explanations • Engaging in argument from evidence • Obtaining, evaluating, and communicating information

Crosscutting Concepts • Patterns • Cause and effect: Mechanism and explanation • Scale, proportion, and quantity • Systems and system models • Structure and function

Disciplinary Core Ideas • LS1: From Molecules to Organisms: Structures and Processes • LS2: Ecosystems: Interactions, Energy, and Dynamics • LS3: Heredity: Inheritance and Variation of Traits • LS4: Biological Evolution: Unity and Diversity

GLOSSARY

adaptation: a physical or behavioral characteristic that helps an organism survive in a particular habitat. Adaptations are evolutionary responses to changing environments.

cladogram: a branching diagram depicting how organisms are related to one another. Branching points represent where advanced features appear and species diverge from common ancestors.

coprolite: fossilized animal poop. Coprolites contain clues to what animals ate and how their digestive systems worked.

CT scan: computed tomography, an x-ray scanning technique that stacks multiple slices of an object into a three-dimensional model

dinosaurs: a diverse group of animals that includes tens of thousands of extinct species, from *T. rex* to *Triceratops*, and all birds. A defining feature of dinosaurs is a hole in the hip socket that allows them to stand upright. All non-avian (non-bird) dinosaurs went extinct about 66 million years before present (mybp); birds are living dinosaurs, and their closest living relatives are crocodiles.

ecological niche: a term used to describe the living and nonliving factors necessary for the survival of a species, along with the ecological role a species fills in a community

evolution: the process of descent with modification, caused by the accumulation of genetic mutations that are selected by the environment

fossil: traces or remains of ancient life—including bones, teeth, shells, leaf impressions, nests, footprints, and chemical signatures—that are typically preserved in rocks

genus: a principal taxonomic classification that is broader than species and narrower than family

paleontologist: a scientist who studies the fossil record

theropod: a diverse group of mostly carnivorous dinosaurs that includes tyrannosaurs and birds, among others

CREDITS

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Chase Private Client

Virtual reality experience created in collaboration with HTC VIVE.

Photo Credits

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