American Museum of Natural History

Educator's Guide

DINOSAUR DISCOVERIES

Ancient Fossils, New Ideas

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BEFORE YOUR VISIT

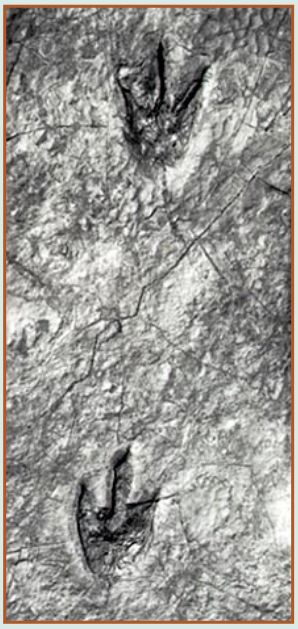
These are ideas for discussion to engage your students before your visit to the *Dinosaur Discoveries: Ancient Fossils, New Ideas* exhibition. (*Answers in parentheses.*)

What do you know?

Many of the discoveries presented in this exhibition contradict earlier notions scientists had about dinosaurs. These discoveries are based on new ways of analyzing ancient fossils, such as using computer software to re-create the muscles of a dinosaur. Ask students to think of something that they used to think but changed their minds when confronted with new evidence. Was there a time when an idea they had was *reinforced* by new evidence?

What is a fossil?

Many people think of fossils as the remnants of animals long gone, when in fact these are only one type of fossil. Other fossils, called "trace fossils," are evidence of something a dinosaur left behind but were not part of the dinosaur itself. Write the words "body" and "trace" in two columns on the board. Tell students that fossils are classified as body fossils and trace fossils. Have students come up with body fossils (*skull, tooth, foot, etc.*). Write their answers in the column marked "body." Further explain that trace fossils are remnants of the dinosaur, and not the dinosaur itself. Ask students to suggest what trace fossils may be (*footprints, skin impression, eggs, nest, and coprolites [fossilized feces]*). Write their responses in the column marked "trace."



Dinosaur tracks are one kind of trace fossil.

Kid biomechanics

Biomechanics is the study of the relationship between the way you move and your body size and shape. Today, scientists use biomechanics to learn how dinosaurs most likely walked or ran, and moved their necks and tails. Ask students to think about how their joints work by comparing the motion of their knee to the motion of their wrist, elbow, or shoulder. What are the similarities and differences? *(Knees and elbows act like hinges. Think of how a door can open and close, but does not operate in any other direction. Shoulders are ball-and-socket joints and have a wider range of motion. Wrists are universal joints and can move in any direction.)*

Living dinosaurs

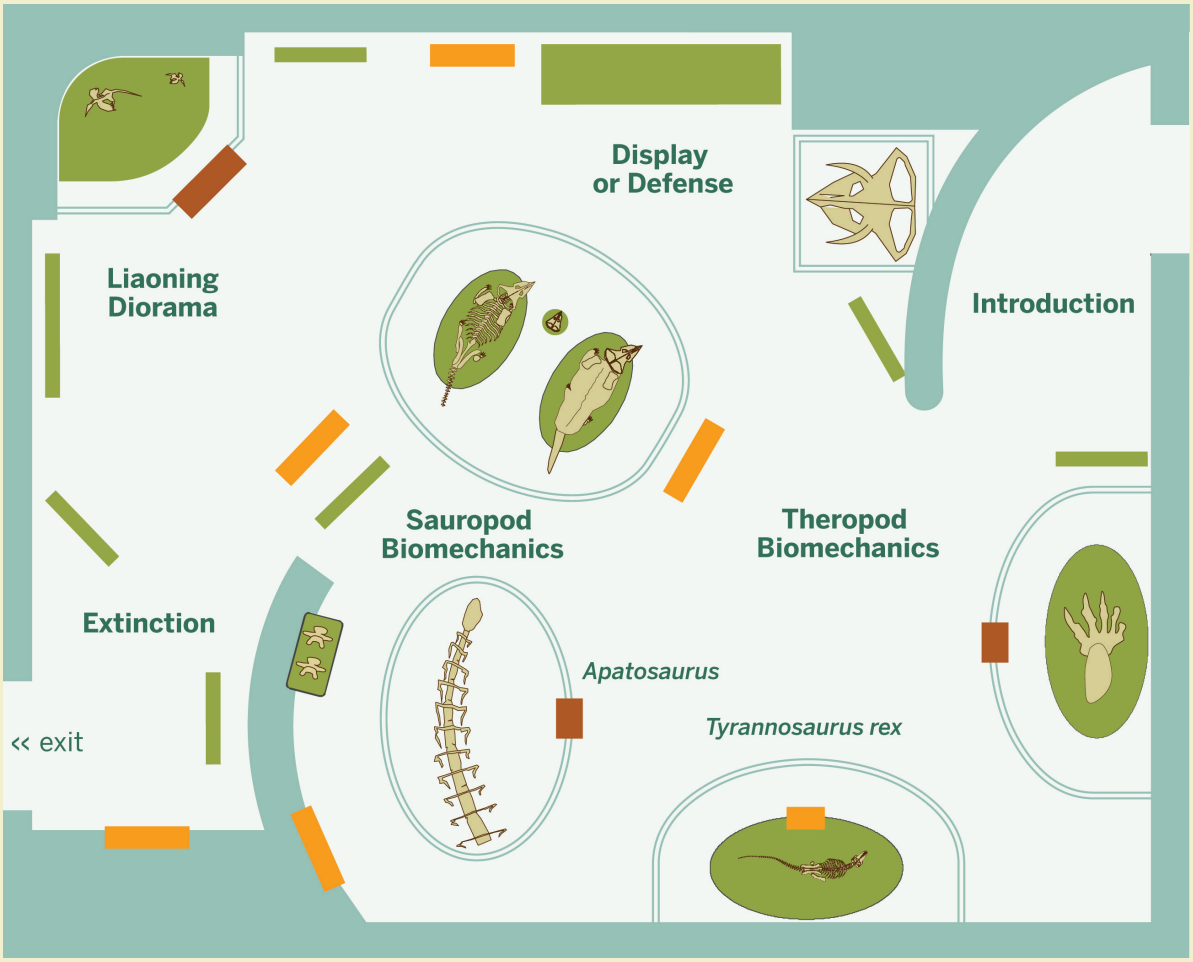
Among the highlights of this exhibition is *Dilong paradoxus*, a dinosaur covered in feathers with a skeleton almost identical to a modern bird. This discovery, and many others, provides scientists with even more evidence that birds are living dinosaurs. Show your students a picture of bird and dinosaur skeletons and ask them to identify similarities between the two. (See "Observe a Dinosaur" activity on last page.)

***Dilong paradoxus*, a smaller cousin of *T. rex*, in his native habitat.**

Why feathers?

Modern birds may be dinosaurs, but scientists have evidence that other dinosaurs had feathers but did not fly. Some dinosaurs had very simple feathers. Other dinosaurs had more advanced feathers, similar to those found today on modern birds. Ask students to think about what dinosaurs might have used feathers for. *(Flight, insulation, defense, display, camouflage, waterproofing.)* Have them give examples of animals that use feathers or other purposes.

MAP OF THE HALL



KEY:

- Interactive
- Video
- Case/Display

Theropod Biomechanics:

How fast could *T. rex* run? A scale model *T. rex*, alongside an animation depicting how this enormous animal moved, provide some clues.

Sauropod Biomechanics:

Could huge animals such as *Apatosaurus* hold their necks and tails high? Scientists use engineering principles, complex computer models and the study of living animals to investigate this question.

Display or Defense

What purpose did dinosaurs' elaborate horns and frills serve? An impressive display of dinosaurs skulls, as well as horns from living animals, provides context for the debate over function.

Liaoning Diorama

Exceptionally preserved fossils discovered in the Liaoning Province in northeastern China have enabled scientists to reconstruct plants and animals in stunning detail. A vivid diorama introduces topics such as the process of fossilization, feathered but flightless dinosaurs, and the origin of flowering plants.

Extinction

What happened 65 million years ago that caused the extinction of over half of living plants and animals? Research suggests that the answer is complicated: A combination of a massive meteorite impact, volcanism, and extreme climate changes.

KEY CONCEPTS

Use the concepts below to connect the exhibition's themes to your curriculum.

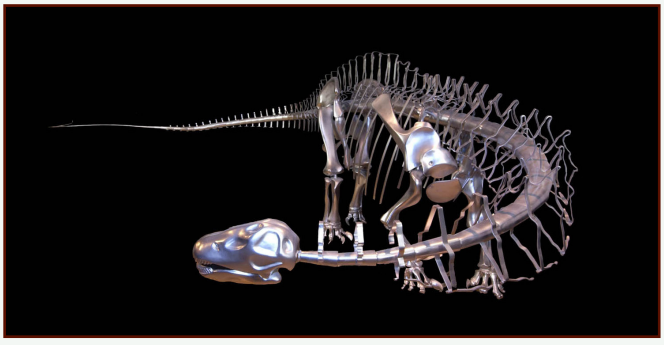
Scientific understanding relies on evidence.

Scientists develop explanations using observations (evidence) and what they know about the world (scientific reasoning). This exhibition presents several types of evidence for new theories about dinosaurs:

- **New fossils.** Since the early 1990's, thousands of ancient plants and animals have been discovered in the Liaoning Province in China. One of these fossils is *Dilong paradoxus*, a primitive cousin of the *Tyrannosaurus rex*, which is covered in feathers. This find reinforces the idea that birds are living dinosaurs. Other fossils, like the juvenile *Psittacosaurus* found in the belly of a primitive mammal fossil, call into question the theory that mammals were much smaller and not in competition with dinosaurs.

***Dilong paradoxus*, a smaller cousin of *T. rex*.**

- **New technology.** Scientists today use computer-based technology to enhance the gathering and manipulation of data, particularly when dinosaur skeletons are incomplete, or too fragile (and heavy) to handle. The exhibition's scale model *Tyrannosaurus rex* shows a rendering of how this giant actually moved, and an aluminum *Apatosaurus* model simulates this enormous creature's range of motion.



Full scale aluminum *Apatosaurus*.

Modern birds like chickens provide information about how extinct dinosaurs moved.

- **New ways of looking at old fossils.** Scientists study modern animals for clues about the behavior of ancient dinosaurs. Because non-avian dinosaurs have been extinct for at least 65 million years, understanding behavior and movement poses a real challenge. Scientists observe movement, tracks, and morphological features in living species, from chickens to crocodiles, in order to flesh out what we know about ancient animals such as extinct dinosaurs.

Technological tools help scientists make more precise measurements and observations.

For centuries paleontologists have relied on tools such as hammers, shovels, and compasses. But now scientists also study dinosaurs with everything from satellite technology to scanning electron microscopes. These technologies are helping paleontologists piece together more of the dinosaur puzzle than ever before. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used. These technologies help paleontologists:

- **Discover fossils faster.** GPS systems help scientists navigate to new dig sites (and relocate existing ones).
- **Examine dinosaur locomotion:** Computer-generated models replicate dinosaurs' speed, movement, and range of motion.
- **Simulate dinosaur behavior.** Scientists are using computer models to simulate dinosaur herding behavior based on fossilized dinosaur tracks.
- **Peer inside fossils.** Scientists can look inside fossils, like the fragile skull of the feathered *Bambiraptor*, without breaking them, thanks to advanced imaging technology such as digital x-rays and CAT scans.

A scale model *T. rex* sheds light on biomechanics.

Scientific knowledge is subject to change as new evidence becomes available.

Scientific knowledge evolves over time, building on earlier knowledge. Many theories about dinosaurs are undergoing major revision, such as:

- **Dinosaur extinction.** For decades the leading theory about the extinction of dinosaurs was that a huge asteroid or comet slammed into Earth 65 million years ago, setting off global wildfires and blocking sunlight. In recent years, however, researchers have also been investigating whether other forces contributed to a drastic change in the environment, such as massive volcanic eruptions and changes in sea level.

- **Speed and range of movement.** About a century ago, *T. rex*'s discoverers wrote of its "destructive power and speed." Within decades, though, scientists had decided that all large dinosaurs, including *T. rex*, were sluggish giants. Later, views changed again, and *T. rex* regained its reputation as a fast, fierce carnivore. These days, *T. rex* may be slowing down once more. Recent biomechanical analysis suggests that while *T. rex* was a powerful, even "destructive" animal, it wasn't very fast.

- **Frills and horns:** Researchers have long wondered about the purpose of particular dinosaur features like the bony horns, crests, and plates sticking out of their backs. For years, paleontologists thought these features served to protect the animal in battle. More recently, scientists have come to another conclusion: Some of the features were used by dinosaurs in competition for mates.

Science relies on human qualities of reasoning, insight, skepticism, and creativity.

Paleontologists do much more than dig for and assemble dinosaur bones—they develop innovative ways of solving problems, posing questions, and obtaining data. Scientists formulate and test their explanations of dinosaurs using:

- **Observation:** It's more than just a keen eye. Paleontologists determine what to observe and how to apply those observations. For example, paleontologists observed male bighorn sheep engaged in head-to-head combat to determine whether horned *Pachycephasaurs* fought in the same way. Comparing the skulls of the two animals didn't provide enough information to determine their behavior.

- **Experiments:** Birds are living dinosaurs, so studying the way large modern ground birds—ostrich, emu and rhea—walk and run can help scientists interpret extinct dinosaur footprints. Experimenters got the birds to walk across a footprint-friendly surface, and then photographed and measured the results.

- **Models:** After astronomers recorded a comet crashing into Jupiter in 1994, computer scientists have modeled the collision to show what might have happened when a meteor hit Earth. Models help scientists visualize and extrapolate from events that cannot be directly observed.

BACK IN THE CLASSROOM

These are follow-up discussions and activities to do with your students after visiting the *Dinosaur Discoveries: Ancient Fossils, New Ideas* exhibition.

WRITE about the exhibition

Ask students to write an article for the school newspaper that describes the exhibition. What would they emphasize, and why? What objects from the exhibition would they choose to illustrate those points?

DISCUSS the evidence

Some of the new discoveries from the exhibition came about through the use of new technologies. Some from the discovery of new fossils. Others through the use of new methods, like analyzing the behavior and mobility of modern animals and comparing that data with dinosaur fossils. Ask your students what new things they learned about dinosaurs from the exhibition. Make a list on the board. Ask students, How did these new discoveries come about?

DRAW: Form follows function

Many of the dinosaurs in the exhibition had elaborate features like domed heads, horns, and frills. Ask your students which modern animals have features with similar functions. What animals have elaborate features that are used to attract mates? What animals have features that are used to fight other animals within their own species? What animals have features that are used for defense? Have younger students design their own dinosaurs. Tell them first to write down the traits they would like their dinosaur to have. Then they should draw a sketch of their dinosaur on paper. Have them explain why their dinosaurs look the way they do.

Triceratops **sporting horns and frills**

MEASURE: Human trackways

What can we learn from looking at dinosaur trackways? There's a lot we can't tell, like the size, color, and sex of the dinosaurs which made the tracks. One of the things that paleontologists can tell from looking at a dinosaur track is whether the dinosaur was running or walking. Have your students try this activity to show the difference: Find a setting where you can see your footprints (sand, snow, or mud). First walk, then run over the same area. For each set of prints, measure your stride (the distance from toe to toe made by the same foot). What are the differences in your stride between your two sets of prints? Ask a friend who is taller or shorter to repeat the same activity. Compare and contrast your footprints.

RESEARCH: Modern extinctions

Ask students to recall what they learned about the extinction of the non-avian dinosaurs. What different theories do scientists have about the mass extinction 65 million years ago? Then, discuss the factors that are causing modern extinctions. Are they avoidable? What modern animals are endangered or have recently become extinct? Divide the class into groups and ask each group to research and report on an endangered animal.

Direct your students to **www.worldwildlife.org** for more information on endangered species.

BRAINSTORM: Remaining mysteries about dinosaurs

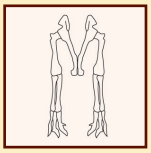
What colors were dinosaurs? Have students give different arguments for different potential colors. Why are particular animals certain colors? (Why aren't there blue horses just as there are blue fish or blue birds? Why are penguins all black except for their white bellies?) What are some other unanswered questions about dinosaurs? Ask your students what they would like to know about dinosaurs that is still a mystery.

ONLINE RESOURCES

To download these free resources which further explore themes presented in the *Dinosaur Discoveries: Ancient Fossils, New Ideas* exhibition visit our website: www.amnh.org/ancientfossilsnewdiscoveries/educators

Be an Exhibition Explorer in *Dinosaur Discoveries: Ancient Fossils, New Ideas*

This activity booklet guides students through the exhibition, challenging them to examine new clues and discoveries as they explore the exhibition. Worksheets for each section provide guidance for their observations and probing questions.

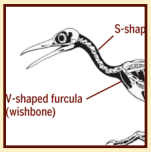


Thump, Thump, Thump ... How Dinosaurs Moved

See firsthand how a dinosaur moved! Observe a bird as it walks along the sidewalk or in your backyard. Then challenge a friend to a "push-up" race—dinosaur versus crocodile.

Be a Sleuth: How Dinosaurs Behaved

Like today's crime-scene investigators, paleontologists study clues left behind. Try your hand at interpreting fossilized footprints.



Observe a Dinosaur

Investigate modern birds for a look at how ancient dinosaurs may have moved and behaved.

Dino Times! How Dinosaurs Lived

Travel to Liaoning, China, where a fossilized lakebed is providing scientists with the most complete picture to date of what a dinosaur ecosystem may have looked like.

Fossilized Fashion: How Dinosaurs Looked

We know that some dinosaurs had fancy frills while others had sharp horns or pointy spikes. But why? Investigate the purpose of these and other dinosaur "fashions."

Make Your Own Liaoning Diorama

Re-create the 130-million-year-old forest in what is now China to understand why this fossil site is of such vast scientific importance.

CREDITS

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