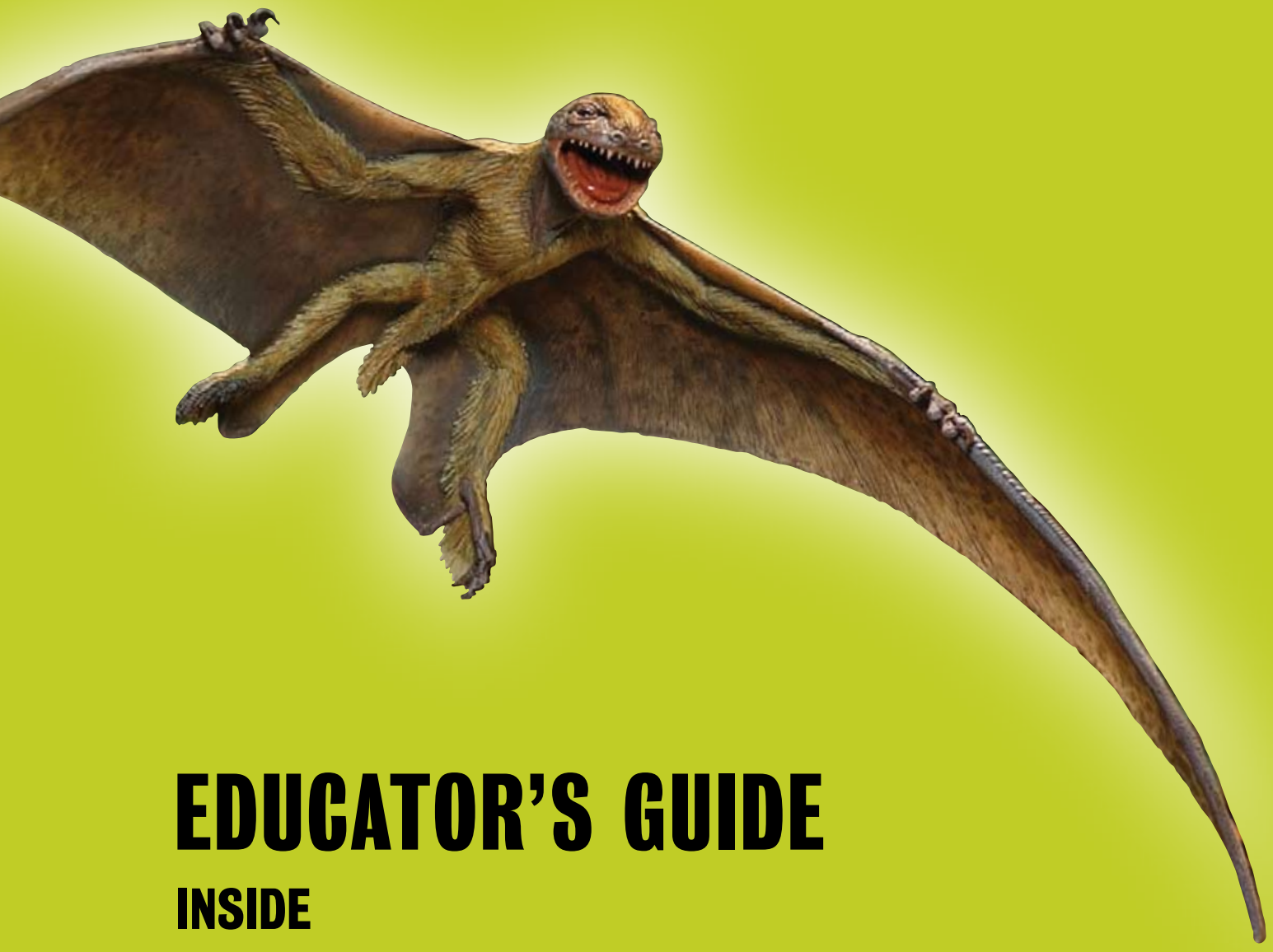
DINOSAURS

ANCIENT FOSSILS, NEW DISCOVERIES



EDUCATOR'S GUIDE

INSIDE

- Key concepts to prepare for your visit
- Gallery inquiries and classroom activities for your students
- California Content Standards for each applicable section

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Dear Educator,
Welcome to *Dinosaurs: Ancient Fossils, New Discoveries*. This guide includes an exhibition overview, links (in colored text), and curriculum to help make your Museum visit an engaging, educational experience.

References to California Content and English Standards are included where appropriate. Full text of standards is available at http://www.cde.ca.gov/index.asp.

If you have questions related to this guide, please call the Museum Education Department at 619.255.0311 or email education@sdnhm.org.

Dinosaurs: Ancient Fossils, New Discoveries is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with the Houston Museum of Natural Science; the California Academy of Sciences, San Francisco; The Field Museum, Chicago; and the North Carolina Museum of Natural Sciences, Raleigh.

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ABOUT—
Dinosaurs: Ancient Fossils, New Discoveries

Dinosaurs: Ancient Fossils, New Discoveries highlights recent advances in our understanding of how dinosaurs looked, moved, behaved, and died. Scientists are using new fossil evidence and new technologies to address long-standing mysteries and to form new theories about the distant past.

The exhibition is divided into five sections:

Biomechanics
Trackways
Display or Defense?
Liaoning Diorama
Extinction

Each section includes stunning specimens, engaging computer interactives, and videos of scientists using exciting new technologies from satellites to software design to see beyond the fossil record.

PREPARE—key concepts

SEEING THE UNSEEABLE—SURPRISE!

Traces of life forms preserved within the Earth—fossils—provide a blurred view into the distant past. Paleontologists endeavor to interpret this evidence and show us unseen vistas. Crime-scene investigators will lament evidence that has degraded or moved, but paleontologists fear not. They recreate the prehistoric world using data that has been remade by vast geologic forces. Fossil clues are incomplete, hidden in the Earth, and often millions and millions of years old. But far from being a trail gone cold, the study of prehistoric life is red hot. In the last two decades, new fossil discoveries and the application of new technologies have changed the way we imagine the awesome creatures of the Mesozoic Era. What we know about dinosaurs is changing every day.

Surprise! Dinosaurs are still with us in their avian form. Birds are elegant and compelling ambassadors of evolution. The fossil record shows that modern birds share a common ancestor with the ferocious meat-eating dinosaurs, the theropods. Modern paleontology and advanced technology allow us to see the fossil record and the life around us in new and surprising ways.

Ask your students to examine *Dilong paradoxus* either on the web before your visit or in the Liaoning Diorama section of the exhibition. *Dilong paradoxus* was covered in feathers and had a skeleton almost identical to a modern bird. This discovery is telling evidence; birds are actually living dinosaurs! Ask your students to study and discuss the skeletal structure of this little tyrannosaurid and a modern bird. What do the similarities suggest about dinosaurs, birds, and the theory of descent with modification?

http://news.nationalgeographic.com/news/2004/10/photogalleries/feathered_dinosaur/photo3.html

http://www.geologyrocks.co.uk/tutorials/origin_and_early_evolution_birds

California State Content Standards

Grade 3 Life Science 3 a–e

Grade 7 Evolution 3 a–e

Grades 9–12 Ecology 6 a, g

Grades 9–12 Historical and Social Science Analysis Skills; Research and Point of View 1

Grades 9–12 Historical and Social Science Analysis Skills; Chronological and Spatial Thinking 3

Have you ever seen a picture of a *Triceratops* using its horns as defense against an attacker? This is something the artist certainly would never have seen. So how do scientists and artists get ideas about the behavior of long-extinct animals? They look at animals that are alive today. The study of living species is another tool paleontologists use to get a closer look at the unseen past. It was once thought that the horns and frills of the ceratopsians, like *Triceratops*, were for defense, but closer examination of fossil evidence and living horned creatures has changed the picture. Surprise! Ceratopsian frills were typically too thin to offer much protection. Modern animals sporting elaborate head gear, like beetles or bison, almost always use their horns to attract mates and compete with rivals for reproductive advantage, and paleontologists believe ceratopsians would have used their fancy heads in the same way.

California State Content Standards

Grade 3 Life Science 3 a–e

Grade 7 Evolution 3 a–e

Grade 7 Earth and Life History (Earth Sciences) 4 a–d

Grades 9–12 Ecology 6 a, g

Grades 1–12 Investigation and Experimentation

Ask your students to consider *Pachycephalosaurus*. How is this bone-domed dinosaur usually depicted? If your students were to direct a film in which two Pachys were engaged in combat for a mate where would they have the rivals land their blows? Would they fight like big-horned sheep, ramming head to head, or with pushing blows to the side of the body like bison? The clues to answer this question are in the Display or Defense section of the exhibition, or on the web: http://animals.nationalgeographic.com/animals/prehistoric/pachycephalosaurus-wyomingensis.html. Get a close look at *Pachycephalosaurus* and then contrast the fighting styles of big-horn sheep and bison.

http://www.youtube.com/watch?v=zj8istSAMoY&feature=fvw

http://www.youtube.com/watch?v=tj_eHhGdygg&feature=related

California State Content Standards

Grade 3 Life Science 3 a–e

Grade 7 Evolution 3 a–e

Grade 7 Earth and Life History (Earth Sciences) 4 a–d

Grades 9–12 Ecology 6 a, g

Grades 1–12 Investigation and Experimentation

NEW DISCOVERIES, NEW TOOLS

At first, fossil hunters had only their wits, a shovel, a compass, and a measure of luck. Today GPS, advanced imaging technologies, biomechanics, and computer modeling are all likely to be in the toolkit of the paleontologist.

Satellite images can be used to locate prospective dig sites. GPS is used to navigate active sites and to map fossil finds accurately. Scientists at The American Museum of Natural History used CAT scans to get a closer look inside the tiny skull of *Bambiraptor feinbergi*. This little *dromaeosaur* was a lucky find for a 14-year-old boy in Montana. It is one of the most complete specimens ever found in North America. Scientists were struck right away by its many bird-like features; hollow bones, s-shaped neck, v-shaped wishbone, folding arms, three-toed feet, and hip-bone orientation, but the CAT scan results revealed an exciting new similarity. *Bambiraptor*'s brain case probably held a brain nearly as large as those of some modern birds.

Ask your students to think about how new ideas result from new discoveries and new ways of analyzing data. Can they think of something that they used to believe that they changed their minds about when confronted with new evidence? Was there a time when they had a theory reinforced by new evidence? Take a look at this CAT scan of a hadrosaur. What new information is likely to come about as a result of this data? http://news.nationalgeographic.com/news/2007/12/photogalleries/dinosaur-pictures/photo5.html

New ways of looking at data allows scientists to imagine how extinct life forms may have lived and behaved. People are extremely curious about what dinosaurs were really like when they were alive and this is hard to get at with just a jumble of bones and footprints to go on. The science of biomechanics is beginning to provide some good answers. Biomechanics applies the principles of physics and engineering to biological movement. Scientists study animals as if they were machines.

Bioengineers build virtual and mechanical animal models. In order to do this they study both the fossil evidence and the related physiology and kinesiology of living animals.

How fast could a *T. rex* run? Biomechanical modeling has indicated that a six-ton *tyrannosaur* would need three tons of leg muscle to sprint. Impossible! *T. rex* probably was a stately walker, like a modern elephant. Did *Apatosaurus* reach high with its long neck to munch on treetops? Computer modeling of fossil neck vertebrae seems to rule conclusively for a low neck profile for *Apatosaurus*. A model is able to far more precisely predict a range of motion because it is a lot easier to move a computer mouse than it is to manipulate a heavy and possibly deformed fossil. *Apatosaurus* vertebrae themselves would have been far, far lighter than the fossil remains.

Ask your students to visit http://www.amnh.org/exhibitions/dinosaurs/theropod/walk.php.

http://www.amnh.org/exhibitions/dinosaurs/sauropod/apatosaurus.php for a preview of biomechanical modeling in the exhibition.

California State Content Standards

Grade 3 Life Science 3 a–e
Grade 7 Evolution 3 a–e
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"THERE'S UNEXPLORED TERRITORY OUT THERE!"

People have been fascinated by dinosaurs since the first dinosaur fossil was identified almost 200 years ago, and today the desire to look back and understand how life on Earth changes has taken on important significance. As we understand more about the reasons for extinction events and the adaptations of surviving species, we understand more about the fragility and the tenacity of life. "It's a great time to be a dinosaur paleontologist," says American Museum of Natural History curator Mark Norell. "There's unexplored territory out there!"

In addition to all the new discoveries and new applications paleontologists are using to learn about dinosaurs' lives, they are also actively investigating what caused an extinction event that wiped out roughly half of all species on Earth 65 million years ago. All the organisms alive today are descendants of the survivors of that extinction event. What contributes to the ability of a species to adapt to vast changes in the environment? Even some dinosaurs, the avian ones, can be counted as survivors, as there are about 18,000 species of modern birds.

Certainly most scientists agree that the impact of a large comet or asteroid played a major role, but had species diversity begun to decline as a result of other forces such as pervasive volcanic activity and retreating sea levels a few million years earlier? Some scientists believe that global climate change may have been a contributing factor before the crowning blow of the Chicxulub cosmic event.

Ask your students to discuss factors that are causing moderns extinctions. Are they avoidable? What modern animals are endangered or have become extinct? Visit http://www.worldwildlife.org/species/index.html?linklocation=footersitemap for more information about endangered species. Or take a closer look at the mountain lion. The home territories of mountain lions can cover hundreds of square miles, depending on the availability of prey. This animal is not listed as endangered, but can your students make a long-term prediction about the future of this species after a discussion of its need for space and expanding human development?
http://www.dfg.ca.gov/keepmewild/lion.html
http://www.dfg.ca.gov/news/issues/lion/depredation.html

California State Content Standards

Grade 3 Life Science 3 a–e
Grade 7 Evolution 3 a–e
Grade 7 Earth and Life History (Earth Sciences) 4 a–d
Grades 9–12 Ecology 6 a, g
Grades 1–12 Investigation and Experimentation

EXPLORE—classroom activities

SEEING THE UNSEEABLE—SURPRISE!

We know you were here.

Many people think of fossils as the teeth or bones of animals long gone, when in fact bones are only one type of fossil. Other fossils, called "trace fossils," are evidence of something an animal left behind but were not part of the animal 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 children come up with body fossils such as:

- skull
- tooth
- bone

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 guess what trace fossils may be:

- footprints
- skin impression
- eggs
- nest
- coprolites (fossilized dino feces)

Do they remember seeing the spider fossil from the Liaoning site? What trace fossil might a spider leave behind?

California State Content Standards

Grade 3 Life Science 3 a–e
Grade 7 Evolution 3 a–e
Grade 7 Earth and Life History (Earth Sciences) 4 a–d
Grades 9–12 Ecology 6 a, g
Grades 1–12 Investigation and Experimentation

NEW TOOLS, NEW DISCOVERIES

Do the tummy tummy shake!

Sometimes dinosaur hunters find skeletons with little bits of rocks where the stomachs would have been. These are called gastroliths and scientists believe that some dinosaurs swallowed them to help with the digestion of tough plant matter. The rocks would act like grinders. There are several species of bird that do this today. Have your students try a little biomechanics to see how this adaptation would function.

First review the fossil evidence:
http://www.amnh.org/exhibitions/permanent/fossilhalls/curatorvideos/ *Click on Gastroliths*

Check on the zoological connection:
http://www.sandiegozoo.org/animalbytes/t-ostrich.html

Build a mechanical stomach:

Fill two clear plastic jars (small ones like the kind peanut butter comes in, or big ones that held candy, cookies, or pretzels) with water and vinegar to simulate stomach enzymes. Add a meal of plant matter (leaves) to both jars. Add gastroliths (stones) to one jar. Shake the stomachs to move the contents around. Which jar does a better job breaking down the plants? (Note: Be ready to shake long and vigorously.)

California State Content Standards

Grade 3 Life Science 3 a–e
Grade 7 Evolution 3 a–e
Grade 7 Earth and Life History (Earth Sciences) 4 a–d
Grades 9–12 Ecology 6 a, g
Grades 1–12 Investigation and Experimentation

"THERE'S UNEXPLORED TERRITORY OUT THERE"

Survivor!

At the end of the Cretaceous period, about half of all the known species on Earth disappeared from the fossil record. Scientists puzzle over why some creatures like frogs, crocodiles, mammals, and birds survived. Why did ammonites die out but their related cousins, the nautiloids, survive? These questions are still being investigated, but scientists believe that the answers will be many and varied. Some factors that contribute to a species' ability to adapt to a changing environment are size, varied food sources and reproductive strategies that result in more surviving offspring. Ask your students to consider our ancient backyard visitor, the opossum—the only surviving marsupial beyond Australia's shores. Their ancestors foraged in the late Cretaceous forests and swamps alongside dinosaurs. What characteristics of an opossum have contributed to its adaptive success?

http://books.google.com/books?id=-esZPRUN_9YC&pg=PT25&lpg=PT25&dq=evolutionary+history+of+opossum&source=bl&ots=8wpgDRgCqt&sig=jIDyI57bb7hv235lWrpQ1cfaiFM&hl=en&ei=flpSS8XdL4-msgPvqsGBCA&sa=X&oi=book_result&ct=result&resnum=1&ved=0CAkQ6AEwAA#v=onepage&q=evolutionary%20history%20of%20opossum&f=false

http://www.biokids.umich.edu/critters/Didelphis_virginiana/

Did you know that you can check out an opossum specimen for further study from our Loan Program? Find out more: http://www.sdnhm.org/education/nature-toyou/index.html

California State Content Standards

Grade 3 Life Science 3 a–e
Grade 5 Life Sciences 2 c
Grade 7 Evolution 3 a–e
Grade 7 Earth and Life History (Earth Sciences) 4 a–d
Grades 9–12 Ecology 6 a, g
Grades 1–12 Investigation and Experimentation

INVESTIGATE: Do dinosaur trackways reveal behavior?

1. **Examine the dinosaur trackways** and draw them here.

2. How many dinosaurs do you think walked over this space? _____

Dinosaur trackers, like detectives at an ancient crime scene, study dinosaur footprints for clues to behavior.

3. **Find the case with the right rear foot of the sauropod dinosaur *Diplodocus*.** When paleontologists look at tracks, why is it sometimes difficult to determine the type of dinosaurs that left these prints?

4. **Find the case with the only known *T. rex* footprint.** Why are the footprints of this meat-eater so rare?

INVESTIGATE: What purpose did dinosaurs' horns and frills serve?

1. **Pick a fossil skull** with horns and frills. Draw it in the box. Write what kind of dinosaur it is.

2. What do paleontologists think these horns and frills were used for?

3. What modern animals does your fossil compare to? List them here.

4. What do scientists learn from studying these modern animals?

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