ART TO ZOO

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Digging Up Dirt
How Paleontologists Bring Dinosaurs Back to Life

Each year, thousands of visitors stroll through dinosaur exhibits in museums across the country. They crane their necks to see the top of *Brachiosaurus's* skeleton and marvel at the ferocious look of *Tyrannosaurus rex.* Adult visitors try to comprehend the passage of time when it's counted in hundreds of millions of years instead of hours. Dinosaurs make adults think about evolutionary change and abrupt extinction; they wonder what the dinosaurs' experience on earth can teach us.

Rather than being merely curious, children are passionate about dinosaurs. They gaze at the huge skeletons, imagining a landscape that could hold such creatures. They read and mouth the difficult-to-pronounce dinosaur names. Children possess encyclopedic knowledge about dinosaurs. Any teacher who has studied dinosaurs with a class has been corrected by a ten-year-old expert. "Actually, Ms. Miller, since the 1970s, *Iguanodon* has been depicted with the tall aloft." Children are fascinated by the unique place dinosaurs occupy in the panoply of monsters. Dinosaurs were huge, ferocious, preposterous-looking and, best of all, real. They require none of the suspended disbelief that Red Riding Hood's wolf calls upon. Their gigantic forms strike awe without causing fear since they are not merely dead, they are extinct.

However, few people understand paleontology, the science that brought dinosaur remains to human understanding. The purpose of this issue of *Art to Zoo* is to introduce you and your students to this uniquely speculative science. First you will be introduced to a practicing paleontologist, John Horner, and his remarkable discoveries about how dinosaurs nurtured their young. The next sections tell how fossils form and how paleontologists find, stabilize, and transport fossils from the field to the laboratory. In the Practicing Paleontology section, students participate in activities designed to help them think about the fossil record the way paleontologists do. The Pull-Out Page invites students to collaborate in science teams and to create miniature model fossil finds. In addition to the fun they will have with boxes of sand, chicken bones, and plaster of Paris plant fossils, students will learn about geology, paleontology, anatomy, and scientific method.

American Museum of Natural History

How many paleontologists does it take to mount a Diplodocus *leg? This huge sauropod dinosaur demanded the talents of seven men.*

Background

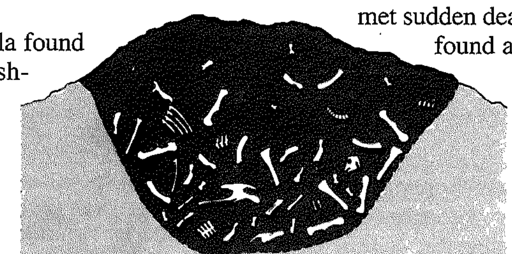
Discovering the "Good Mother Lizard"

John R. Horner is a famous paleontologist (a person who studies ancient life) whose analysis of the dinosaur remains he found in Montana have led many people to believe that at least some dinosaurs took care of their babies after they were hatched. Before Horner made his discoveries, most paleontologists believed that dinosaurs, like most reptiles, merely deposited their eggs and left the infant dinosaurs to fend for themselves. Learning about John Horner's discoveries will teach you a lot about dinosaurs, but it will also teach you how paleontologists think and how they pose the questions that shape what they look for, and thus, what they find.

In 1978, John Horner, a paleontology technician working at Princeton University, was interested in finding the remains of baby dinosaurs. He had read about the few places such remains had been found in the past, such as Mongolia, Canada, Montana, and New Mexico. His research had given him the idea that he might find more juvenile dinosaur remains in a fossil-rich rock formation in Montana, called the Two Medicine Formation. Choosing a place to look for bones is often the first important choice a paleontologist makes, and John Horner had chosen his site. Baby dinosaurs had been of special interest to him since he had found the Western Hemisphere's first intact dinosaur egg while out prospecting in 1977. He had more than a hunch that looking for baby dinosaur fossils in the Two Medicine Formation would pay off.

Though his scientific plans had been carefully made, John Horner's first discovery of a baby hadrosaur's jawbone occurred while he was rummaging through a coffee can full of dinosaur bones in a rock shop in Bynum, Montana. The shop owner had discovered the bones and saved them. She was glad to show them to Horner, and he identified them for her. He believed the tiny bones belonged to a baby duckbilled dinosaur, or hadrosaur, a common type of dinosaur during the Late Cretaceous Period, 84 to 72 million years ago. She took him to the place where she found the fossils, and John Horner's search for the babies began.

John and his partner Bob Makela found fossils (which looked like grayish-black bits of stone) sitting right on top of the small mound they had been shown. When they dug into the mound to see what the ground held, they discovered many baby dinosaur bones mixed haphazardly into green mudstone. Digging deeper, however, they saw that the green mudstone sat within a large, shallow bowl of red mudstone about six feet wide and three feet deep. They theorized that the red mudstone bowl could have been a nest for the babies. It looked as if it had been made by the babies' mother who had mounded up the earth and scooped out the middle. They believed the green mudstone had filled the nest during the many millions of years since the babies had died. When Horner finished digging through the small mound, he had found the remains of 15 three-foot-long baby dinosaurs. (Adult hadrosaurs of the type found in this nest grow to be 25-30 feet long.) These were not 15 complete skeletons. They were disconnected bones belonging to 15 babies who had died in the nest and whose skeletons had been subjected to time and weather until they fell apart; then they were fossilized.



This drawing of the dinosaur nest shows the red mudstone "bowl" that held the mixed-up remains of 15 baby dinosaurs. Braginetz and Ellingsen, *Digging Dinosaurs*

John Horner had many questions about these baby dinosaurs. Reading these questions and learning about how he answered them will help you understand how a paleontologist thinks. If you had made this discovery, what would your questions have been?

First, Horner wondered if these were babies' remains or the remains of another kind of very small dinosaur such as *Microvenator*, who was 3-5 feet long when full grown and weighed a mere 12-15 pounds. In order to answer his questions, he had to "read" the evidence found at the site: the number, condition, and placement of the bones, and the soil type. The first thing he did was to look at the development of the bones. His close examination told him that these were indeed the bones of baby dinosaurs. The signs that he read were found in the vertebrae (bones of the spine) near the base of the spine. These vertebrae were not yet fused together as they are in mature dinosaurs. When he saw that the ends of the limb bones were not fully formed either, Horner knew these were the remains of very young dinosaurs.

But these were not merely newborn babies who had met sudden death right after their birth. Horner found a sign of their age from a source that yields a great deal of information; he looked at the babies' jaws and teeth. He found that their teeth were worn down from chewing. In order to show wear on their teeth, these babies must have been chewing for some time. Their worn teeth

Continued on page 2

continued from page 1

showed that they could not have died immediately after birth.

Another aspect of this find was interesting and perplexing. The nests were filled with bits of crushed eggshell. How would you have explained the crushed eggshells? Horner believed that the babies had stayed in their nests for the early part of their life and that they trampled their own eggshells after they were born.

Now, here are the next thoughts that went through Horner's mind. The babies' teeth were worn down from eating; fifteen of them had been found in the same nest, and all the eggshells in the nest were broken up. It sure looked like the babies had stayed in the nest for a long time. And if they actually did stay in the nest, someone had to bring them food for them to survive — someone, Horner believed, like their mother. The idea that the parent dinosaur would care for the baby dinosaur was unheard of until this time, and it caused a lot of controversy. Furthermore, this was a newly discovered species of dinosaur. Much later, after they'd found and studied a skull of an adult dinosaur of the same type, and compared it to all others previously discovered, they confirmed that this was a new species. They named it *Maiasaura peeblesorum*, which means "Good Mother Lizard."

Horner and his colleagues went back to the same site the next year to look for more nests. Instead of blind luck, which had led them to their first baby bones, this time they were relying on scrutiny. They crawled on their knees over sharp rocks keeping their eyes about a foot away from the ground, looking for eggshell fragments to indicate a nest. Their hard work paid off, and after they had studied the same area for two more years, they discovered a total of eight maiasaur nests.

The next two years brought even more exciting discoveries. Horner's measurements revealed that the maiasaur nests were spaced 23 feet apart. Can you explain why they were always this far apart? He believed that since 23 feet is the average length of an adult maiasaur, the mothers who made these nests kept them one "body length" apart so they would be close, but not too close. Further digging revealed the kind of remains Horner had been looking for. He found eggs that had never hatched, 14-inch-long maiasaur babies, and finally, a site that gave a clear picture of the eggs and nests. The oval eggs were about 8 inches long and were not smooth like chicken eggs but were ridged. They were arranged as two concentric circles, one layer of eggs below the other layer.

John Horner went on to make many other fascinating discoveries, including the eggs and nests of another brand-new species of dinosaur, which he named *Orodomus makelai*, after his colleague Bob Makela. He also found the remains of a herd of 10,000 adult maiasaurs! His experience shows that no matter how many millions of years old dinosaur remains may be, a paleontologist's interpretation of the bones' message can add new, startling information to our understanding of the past.

Paleo-Puzzles

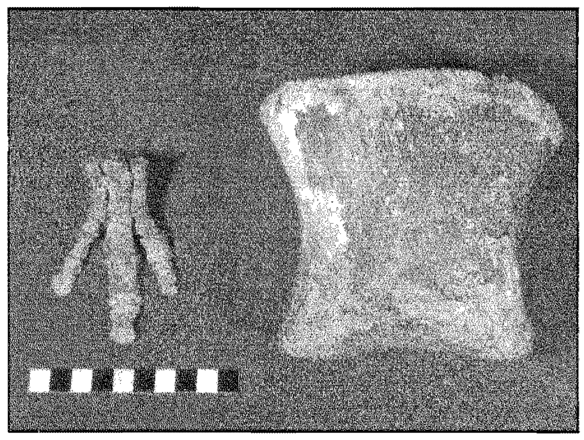
These challenging questions are the type that face paleontologists all the time. Match your wits with the professionals' by suggesting answers to the following Paleo-Puzzles. Find the solutions on page 4.

Paleo-Puzzle I You are excavating a well-preserved dinosaur skeleton. You have been working back to front, from the tip of the tail toward the head, when your digging reveals a sharp change in the kind of rock you are digging in and, sadly, no more skeleton. Where is your dinosaur's head? What force made the rock type change so abruptly?

Paleo-Puzzle II Even an energetic paleontologist would be exhausted by the thought of digging up a sauropod. The tallest sauropod, *Ultrasaurus*, was 55 feet high, and the longest sauropod, *Supersaurus*, stretched 125 feet from nose to tall. In addition to their great size, sauropods present another kind of challenge to paleontologists. Few complete sauropod skeletons have ever been found; most are missing their extremities, such as head, tail, and feet. Further, sauropod skulls are nearly *impossible* to find. Now, knowing what you do about sauropods, can you tell why their remains are so often incomplete?

Paleo-Puzzle III Fossil remains of young dinosaurs are extremely rare, while remains of adult dinosaurs are much easier to find. Why do you suppose this is true?

Paleo-Puzzle IV What unique characteristic of reptiles makes it impossible for paleontologists to say definitively, "This type of dinosaur grew to be 30 feet long and none of them ever grew any longer"?



Donald Baird

Talk about walking in your parents' footsteps! On the left, above the four-inch ruler, is the hind foot of a baby duckbill dinosaur. On the right, you are looking at one toe bone of an adult duckbill!

A Quick Introduction to Paleontology

The science of paleontology relies on several processes. The first process, burial, occurs when bones are buried by tiny particles of rock. The second process, petrification, is the series of chemical changes that cause buried bone to turn to stone. The third process is exposure. Over time, the rock wears away or moves and reveals the bones millions of years after they were buried. Paleontology is itself a process of another kind: the meticulous and fascinating process of finding and studying fossils. Read about all these processes in this section.

How the Earth Makes Fossils

The process of fossilization occurs during the cycle of *erosion* and *deposition*. This cycle is predictable and as old as running water and the earth's crust. Wind and water erode rock, breaking it into tiny pieces that are carried along as grit in the air and as sediment in the water. These sediments settle where the wind and the water leave them, at the river's bottom and the mountain's feet. Over millions of years, the tremendous pressure of accumulating sediments binds these sediments into rock. Shale, mudstone, sandstone, and limestone are types of sedimentary rock. When sedimentary rocks are exposed to wind and water they begin to erode, produce loose particles or grit, and the cycle continues. Fossilization of living things occurs naturally and randomly within this cycle of erosion and deposition.

How Dinosaur Remains Become Fossils

When a vertebrate animal dies on land, scavengers usually tear apart its carcass while feeding. However, if the carcass becomes buried quickly in mud or sand it has a chance of being fossilized because it is not exposed to quick destruction. If a dinosaur dies on a riverbank, or if a flood carries a dinosaur carcass to a body of water, mud and silt from the river may slowly bury its body. The carcass can be buried deeper and deeper on the riverbank as the sediments gather over it or it is covered by the soft sand of the river bottom. The soft parts of the animal's body — the organs, muscles, and skin — decay rapidly, but the animal's bones may remain intact under the protecting sediments.

Over many millions of years, water passing through the accumulating sediments affects the dinosaur bones. The water dissolves some of the chemicals in the bone and replaces these chemicals with others. The new chemicals in the bone preserve the bone's shape and size but give it a different chemical make-up. Sometimes the chemicals petrify the bone, turning it to stone and making the bone much heavier and denser than it was when the animal lived. The "new" petrified bone usually has the same shape as the original, even down to the tiny spaces for blood vessels within the bone.

Over time, water may add minerals to the sediments in which the bone is buried; minerals act as a glue to bind the sediments together. These sediments around the bone harden and become rock, rock that now encases the animal's fossilized bones.

Another turn in the process of fossilization can occur, leaving the print of the dinosaur's remains but destroying the bones themselves. Imagine that the soft sediments have buried the bones. The sediments begin to harden and, like clay or mud, they take the impression of the animal's remains. During the millions of years that the remains are entombed in these sediments they can be dissolved, but their impression in the sediments-turned-to-rock surrounding them lasts. The impression or the stamp of the remains is also a fossil, and it can offer the paleontologist a wealth of information, too. You could say that this kind of fossil teaches us about the foot by showing us the footprint.

A Variety of Fossils

Because dinosaur skeletons are rarely found fully articulated (connected or joined together) paleontologists rely on all the "fossilized information" they find at a site to understand the dinosaur. Fossils come in many forms and instruct eager learners about dinosaurs' physiques and behavior.

Trackways. Dinosaur footprints reveal whether dinosaurs traveled singly, in pairs, or even in herds. Tracks help us understand how rapidly a dinosaur walked, and thus how much food he had to eat to sustain that level of activity. Tracks can show the story of an encounter between dinosaurs.

Plants. Preserved plants offer evidence of the dinosaur's feeding habits. Paleontologists occasionally have found remains of the dinosaur's stomach contents, even such foods as pine needles, and in the case of the recently discovered theropod, *Baryonyx*, fish. Some sites have yielded dinosaur coprolites (fecal droppings) that give specific information about the animal's diet, containing flesh and ground bones if the dinosaur were a flesh-eater, or leaves and seeds for herbivorous dinosaurs.

Geologic Time Scale

Era	Period	Epoch	Beginning of Interval (millions of years ago)	Important Events
Cenozoic (2%)	Quaternary	Recent	.01	Modern man spreads worldwide
		Pleistocene	1.5-2	Many mammals vanish
	Tertiary	Pliocene	5	Oldest known hominids (human creatures)
		Miocene	22-23	Mammals reach their maximum diversity
		Oligocene	37-38	
		Eocene	55	Modern types of flowering plants appear
		Paleocene	65	Spread and diversification of mammals
Mesozoic (4%)	Cretaceous		138	Dinosaurs and many other organisms become extinct Peak of dinosaur diversity; flowering plants appear
	Jurassic		205	First birds
	Triassic		240	First dinosaurs, first mammals
Paleozoic (10%)	Permian		290	Extinction of many animals
	Carboniferous	Pennsylvanian* Mississippian*	360	First reptiles Great coal forests (first conifers, first cycads)
	Devonian		410	First amphibians; first insects; fishes abundant
	Silurian		435	First land life (plants and invertebrates)
	Ordovician		500	
	Cambrian		570	First abundant record of marine life: first vertebrates
Precambrian (approximately 84% of the history of life)				First living things—perhaps 3.5 billion years ago

*The Pennsylvanian and Mississippian Periods *together* are equivalent to Carboniferous

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Paleontologists use fossils to decipher the history of life on earth. The fossil record shows that different plants and animals lived at different times. Paleontologists invented a special "calendar" called a Geologic Time Scale to show who and what lived when. The three eras of ancient life are the Paleozoic, Mesozoic, and Cenozoic. Paleo means "ancient," Meso means "middle," and Ceno means "recent."

Dinosaurs lived during the Mesozoic Era. They were reptiles who so dominated the land that the Mesozoic Era is known as the "Age of Reptiles." The Mesozoic began about 240 million years ago and dinosaurs appeared about 210 million years ago. Dinosaurs' extinction marks the end of the Mesozoic Era, about 65 million years ago. Dinosaurs were the largest land animals of all time — they never flew and did not habitually swim. Flying reptiles, known as pterosaurs, and many marine reptiles lived at the same time as dinosaurs did, but these flying and swimming reptiles were NOT dinosaurs.

Gastroliths. Some paleontologists believe that dinosaurs deliberately swallowed stones, for the same reasons that modern-day chickens peck up gravel. These stomach stones, or gastroliths, stayed in the dinosaur's gizzard and rolled around to more completely grind up the dinosaur's food.

Nests. As we learned in our reading about Horner's finds, fossils may tell us if a dinosaur built a nest for its young. Close analysis of such remains might even reveal how the parents treated their offspring.

Skeletal Remains. These fossils show how the animal was constructed. Teeth, scales, claws or talons, and beaks can be fossils. Bones, the most common skeletal part to be fossilized, may have valuable information preserved upon them, too. Paleontologists can examine bones and see how cartilage, tendon, and muscle attached to them and thus deduce an animal's musculature and its appearance. Bones show traces of disease as well as evidence of combat or injury. A broken bone creates a callus (a hard substance that forms at the break in a fractured bone and reunites the parts) as it heals and shows clearly where the bone reunited. Sometimes paleontologists will find preserved impressions of dinosaur skin; hadrosaur skin was nubby, textured like a football.

Complete skeletons are extremely rare; usually a site contains individual bones or teeth. These bones and teeth are often in poor condition. During their travels in ancient waters and before their burial, the bones are scraped and the joint ends are broken off. Often bones are fractured by the pressure of the sediments piling up above them. A fossil so many millions of years old as a dinosaur bone may be a very plain thing to look at: small, broken, dull-colored and difficult to understand.

Reading the Rocks

Paleontologists believe that there is as much information about a dinosaur locked up in the rocks around the skeleton as in the skeleton itself. They read all aspects of the site closely to understand the fossilized remains. For example, even if a paleontologist finds an intact skeleton, he must also study the rock holding the skeleton. The structure of sedimentary rocks gives important information about the water that deposited the sediments. The speed of the water shows up in the grain size of the sediment. Finely grained sediment is deposited by slow-moving water. Fast-moving water has more energy and carries sediment with larger particles in it. If the remains are found in sedimentary rock with fine particles, the kind deposited by very slow-moving water, you can assume that the dinosaur died near a lake and that the water didn't carry it far. Because it has less energy, slow-moving water is more likely to leave a skeleton well articulated. Another benefit of reading the rock is to gain more information about the climate of the place the animal lived, especially if you study the plant remains too.

Choosing Where to Dig

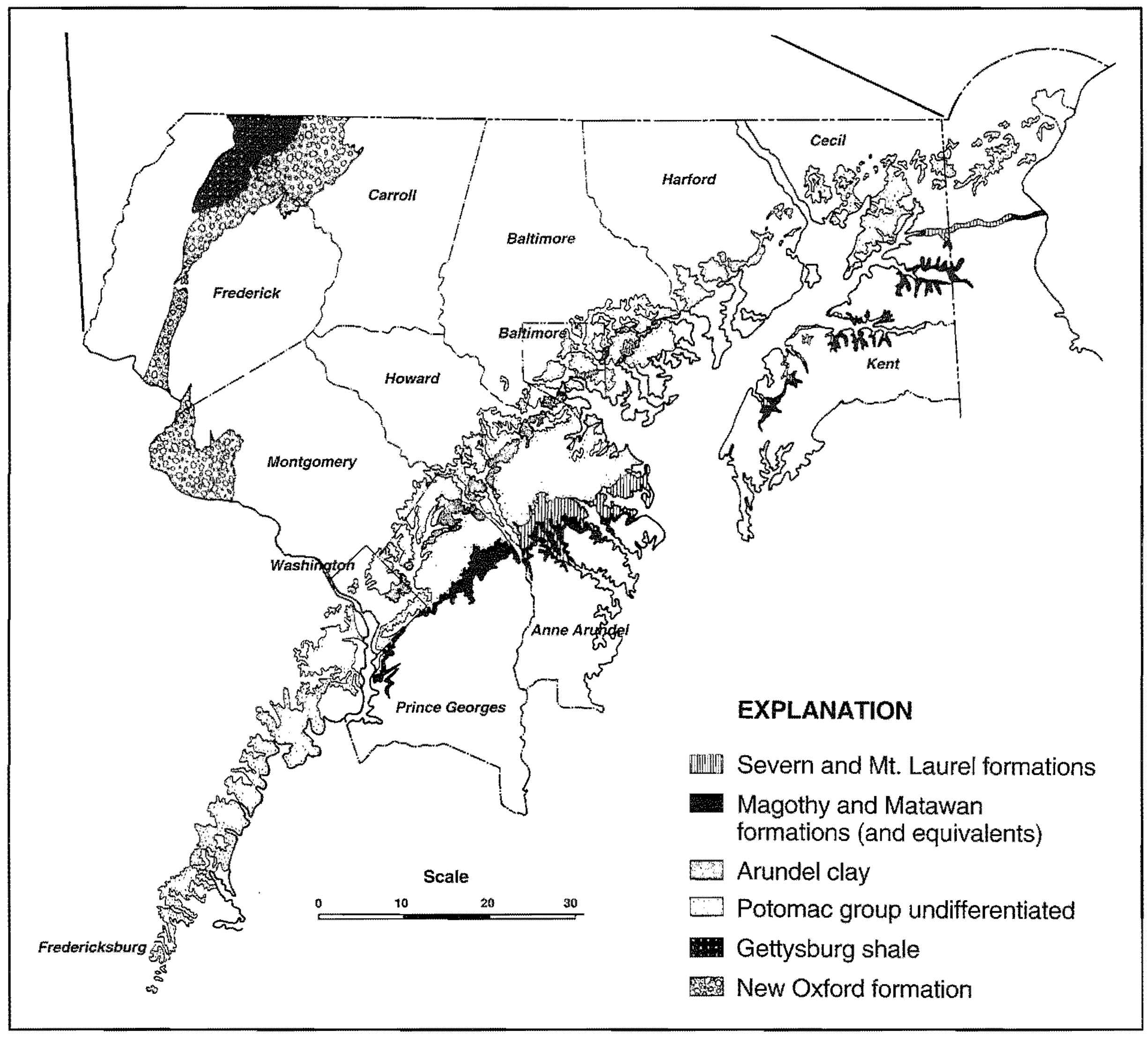
A dinosaur fossil hunter sometimes is lucky enough to see dinosaur remains on the surface of the earth rather than having to dig for them. Such forces as wind and water erosion and volcanic activity can expose rock that is millions of years old. Erosion wears away at the rock covering the fossils. Sometimes, powerful movements under the earth's surface, such as the formation of mountains or the activity of volcanoes, will push very old rock to the surface. Such rock may contain dinosaur remains. Ancient fossil debris may be exposed in the rock and found right on the ground we walk upon.

Paleontologists use special maps, known as geologic maps, to suggest which regions might have dinosaur fossils buried within them. While topographic maps offer information about a region's present-day surface features, such as rivers, roads, and mountains, geological maps tell a paleontologist which places are promising for digging for fossils. Geological maps help identify the name, location, and age of rock formations.

Thus, if a paleontologist knows what he is looking for, he may try to simply go after it. He might sit down with a geological map of his state and look for an area containing rock formations of a certain period. A paleontologist might say, "I'm looking for dinosaurs of the Lower Cretaceous period (144 - 97.5 million years ago) and I'm going to see if I can find any of them in Maryland." The geologic map of Maryland above reveals that the Arundel Clay, cutting a diagonal path along the eastern side of the state, is a rock unit of Early Cretaceous age. As this map shows, a paleontologist would have several options about where to dig to find remains of such Early Cretaceous dinosaurs as the giant flesh-eater *Dryptosaurus*. A fossil hunter would choose where to dig, then go to the site and prospect the area.

Preserving and Transporting Bones

If a paleontologist is lucky enough to find bone she must watch that she does not harm it while trying to get it out of the ground. First, she gently chips away at the rock around the bone using small picks and chisels.



Maryland Geological Survey

Where to begin digging? This geologic map of the state of Maryland shows paleontologists where to find dinosaur-aged rock formations. Which counties promise the best fossil finds?

With the bone still safely embedded in the rock, or matrix, she paints the bone with quick-drying glue to keep it from dissolving into powder as it is exposed to air. After it has been stabilized with glue, she covers the bone with a layer of wet tissue paper. The most protective step is the next one. A jacket is made for the bone so that it can be transported without damage. Using plaster bandages just like the ones doctors use to set broken human bones, or strips of burlap soaked in plaster, the paleontologist "jackets" the bone and the matrix.

Because the fossil is fragile, the paleontologist cannot just dig a hole and pull it out. Instead, she chips away the rock all around the bone except directly underneath it so the specimen within the matrix sits on a pedestal of stone. At this point it looks like a toadstool. Finally, the paleontologist knocks the plaster-jacketed bone off its pedestal, then covers the underside with more plaster bandages to seal it, then clearly labels it "block A," for example, to indicate how the plaster packages fit together for study in the lab.

Of course, dinosaur remains are so large that it is often impossible for a person to carry the jacketed bones away from the site. The remains are sometimes put on a sled and dragged out of the excavation by a bulldozer, then driven to the paleontology lab by truck. Some very large jacketed remains are lifted from the site by helicopter. Even larger finds must be sliced in half just to become manageable for a helicopter!

Cleaning Fossils

Once the fossil has been brought to the lab, the painstaking and slow process of clearing all the rock matrix away from the bone begins. Preparators (technicians who remove fossils from rocks) use all sorts of methods to clean away rock matrix while preserving dinosaur bone. If chisels and knives are not suitable for the fossil remains, or if the risk of a human hand slipping while using a chisel is too great, lab workers use tiny dental drills or picks to clear the bone away. They drill lightly to remove the rock, and then paint newly exposed bone with glue to protect it. If dinosaur bones have been preserved in limestone, preparators may use acid baths to separate rock from bone.

Practicing Paleontology: Activities

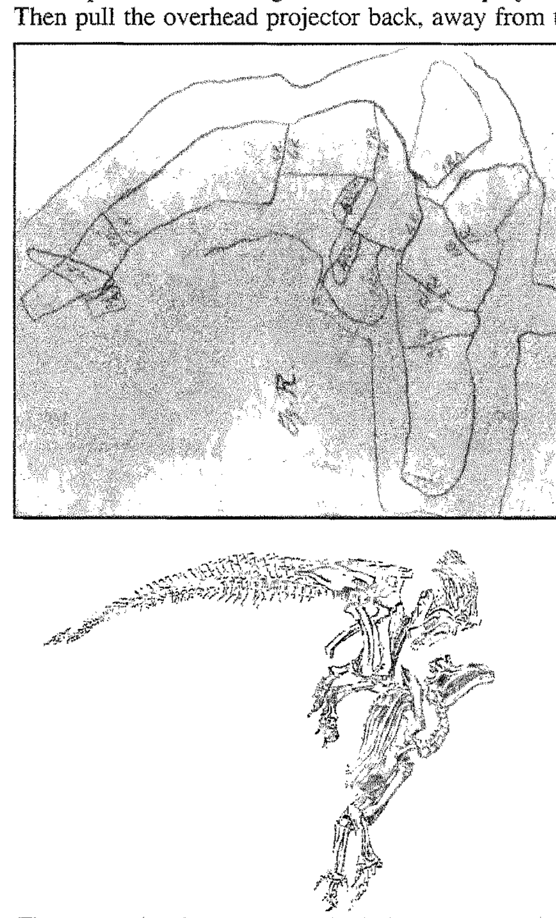
There are more than three hundred kinds of dinosaurs to study, and you are not to be limited to the maiasaurs you read about in the beginning of this issue. Before you do the following activities, visit your local natural history museum or go to the library and look through books about dinosaurs to find one that makes you curious. You might be intrigued by the vicious *Deinonychus*, the four-ton *Allosaurus*, or the seven-horned *Styracosaurus*. For these activities, you should have your "favorite" dinosaur in mind. You should also know as many facts about your dinosaur as possible. Use this questionnaire to help you get ready for the activities.

Dinosaur Background Information

Dinosaur's name____________________________
translation_________________________________
When did this dinosaur live?_____________________
What did this dinosaur eat? _____________________
Was this dinosaur ornithischian (bird-hipped) or saurischian (lizard-hipped)?__________________
Find a picture of this dinosaur's skeleton. Where have this dinosaur's remains been found? ____________
How big was this dinosaur?_____________________
What are the dinosaur's unique features of appearance?________________________
Trace or photocopy a drawing of the dinosaur to use for reference.

Activity 1. Find a geologic map of your state. Where would you choose to hunt for remains of your dinosaur? Why did you choose this region? If there is no area in your state that might yield fossils of the age you need, where is the closest place you could dig?

Activity 2. Draw a picture of one part of your dinosaur's anatomy on a transparency. You might choose to draw only the skull, or perhaps even only one bone, like the femur, or thigh bone. In a darkened room, place the drawing on the overhead projector. Then pull the overhead projector back, away from the



Institut Royal des Sciences Naturelles de Belgique

These two drawings were made during an excavation of an Iguanodon *skeleton in Belgium in 1878. The outline sketch (top) shows how the skeleton was divided into 15 plastered blocks in the field. The drawing of the skeleton (bottom) shows the skeleton exactly as it was found. How do you think the paleontologist used these drawings as he studied the* Iguanodon *in the laboratory?*

Continued on page 4

screen or wall, until the image you have drawn is as large on the screen as it was in real life. Tell your classmates about your dinosaur and about the dimensions of the body part on the transparency, as well as the rest of its "vital statistics." (Of course, you will have to measure out your dimensions before you begin. For example, if your dinosaur's femur was seven feet long, measure out seven feet of string and stretch it out as you enlarge the transparency to know when the image is big enough.)

Activity 3. Paleontologists rarely find a complete skeleton. If they want to mount a skeleton for display in a museum, they will probably have to use some original bones and many fabricated bones. These man-made bones may be casts of originals from other similar skeletons, or replicas of drawings of bones. Using modeling clay, recreate one of your dinosaur's bones or teeth. Making this model will be easier if you can find a drawing of one of your dinosaur's bones from different angles so you can see it from all sides. If it is too hard to model a dinosaur bone from a picture, try modeling a real bone, such as a chicken leg. Remember, modern birds are dinosaurs' remote cousins!

Activity 4. Dinosaur footprints can be fossilized when a special set of circumstances occurs. If a dinosaur made footprints in stiff mud and the indentations hardened, and if the tracks were then covered with another layer of dirt, which would protect the trackway, the prints might be saved for us to study today. Trackways are a valuable source of information for paleontologists because they reveal details about the type, gait, size, and speed of the animal that made them. "Read" these tracks and answer the questions in the caption.

Boston Museum of Science

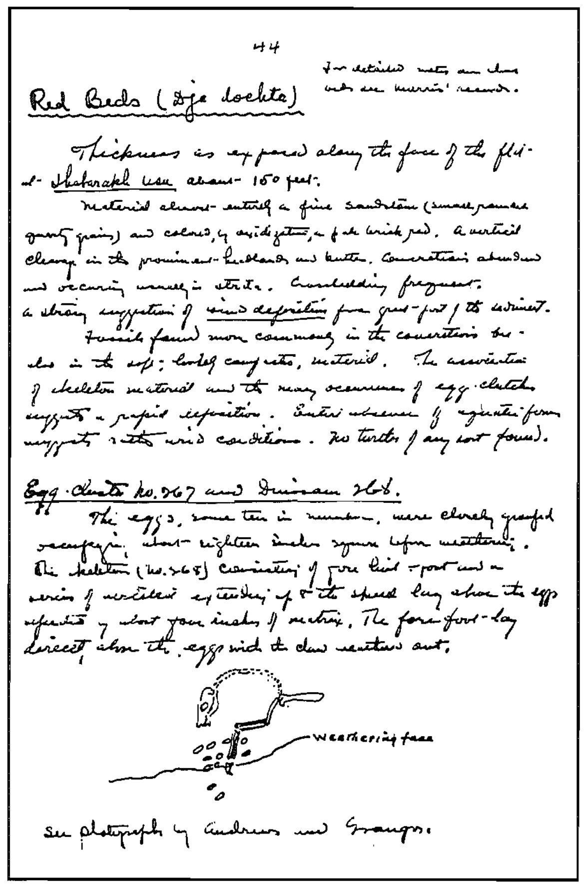
Every picture tells a story. What story can you invent to explain this drawing of dinosaur trackways? How many dinosaurs appear in this tale? are they the same kind of dinosaur? How did this story end?

Activity 5. When a paleontologist discovers dinosaur tracks in the field, the tracks are usually hollow impressions, the kind your foot makes as you walk in wet sand. Because it is more difficult to study the impression a foot makes, a footprint, than a model of the foot sole itself, paleontologists sometimes use the footprint as a mold, and fill it to make a replica of the dinosaur's sole.

Try this experiment with your own footprint. Fill a shoebox with two inches of wet plaster of Paris mixed to the consistency of heavy paste. Firmly press your bare foot into the plaster of Paris, creating an exact impression. This is a mold of your foot. Let the plaster dry, then coat the whole surface (even the plaster that did not receive your footprint) with a thin layer of petroleum jelly. Pour another two inches of thick plaster of Paris into the mold of your foot. Let it dry. Tear away the shoebox, then pull the two layers of plaster apart.

You now have a positive version of your footprint, the cast, and a negative version, the mold. What information can you learn about your foot's sole, skin, and bone structure from the cast that was difficult to detect in the mold?

Activity 6. To record their experiences and to help study their finds in the laboratory, paleontologists keep journals about their discoveries while in the field. These journals contain day-by-day records of the progress of the excavation. The paleontologist draws the location of all the specimens he finds and may make hypotheses about what the finds might be. The paleontologist and field workers will rely on the



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For detailed notes [illegible] see Morris' record.

Red Beds (Dja dochta)

Thickness as exposed along the face of the [illegible] Shabarakh Usu about 150 feet.

Material almost entirely a fine sandstone (small rounded quartz grains) and colored, by oxidization, a pale brick red. A vertical cleavage in the prominent headlands and buttes. Concretions abundant and occurring usually in strata. Crossbedding frequent. A strong suggestion of wind deposition for great part of the sediment.

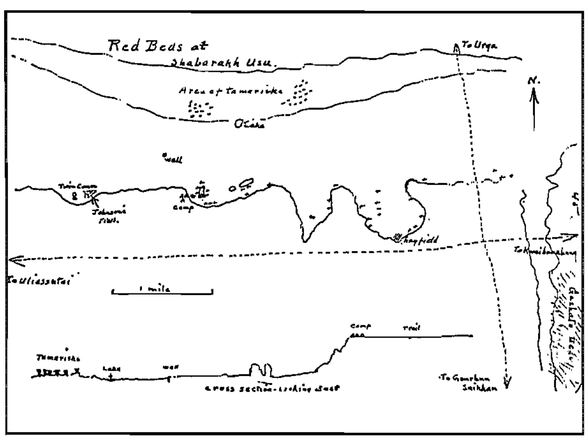
Fossils found more commonly in the concretions but also in the soft, loosely compacted, material. The association of skeleton material and the many occurrences of egg clutches suggests a rapid deposition. Entire absence of aquatic forms suggests rather arid conditions. No turtles of any sort found).

Egg clutch no. 267 and Dinosaur 268.

The eggs, some ten in number, were closely grouped occupying about eighteen inches square before weathering. The skeleton (no. 268) consisting of fore limb + foot and a series of vertebrae extending up to the spinal bay above the eggs separated by about four inches of matrix. The fore foot lay directly above the eggs with the claws reaching out.

Weathering face

See photograph by Andrews and Granger.



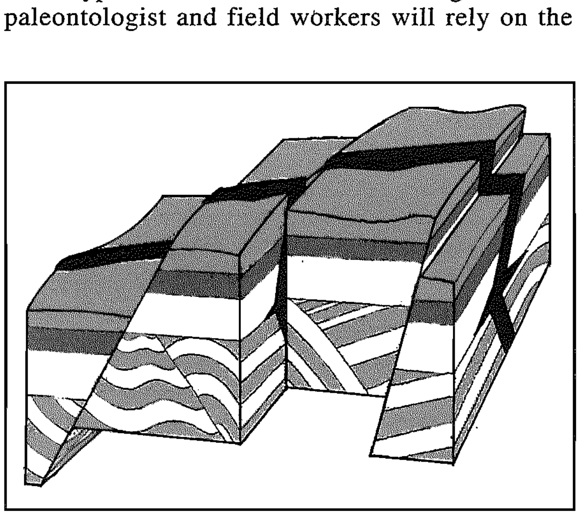
Edwin M. Colbert *The Great Dinosaur Hunters and Their Discoveries*, Dover Publications, Inc.

Walter Granger's field journal contains several different kinds of valuable information: a map of the site, finds, and camp, description of the rock holding the Protoceratops *fossils, and a drawing of the skeleton found near the nest.*

journal when they return to the lab, especially if more than one skeleton was found at the site.

Above are two entries from the field book of famous paleontologist Walter Granger. These notes were made in 1923, while Granger was collecting fossils in Mongolia. This expedition was to yield remarkable results: the skeletons, nest, and eggs of *Protoceratops*. This find, at the Flaming Cliffs, in Bain Dzak, Mongolia, offered the first proof that dinosaurs laid eggs.

Try to read the field journal entry (some words are illegible) and look at the map. What can you learn about the practice of paleontology from these documents?



Quarto Publishing, Crescent Books, Crown Pub., Inc. 1989.

This drawing shows how faults disturb rock layers. The sedimentary rock layers drop, move upwards, or move sideways when the Earth's crust breaks and a fault occurs. A fault can destroy a dinosaur fossil embedded within sedimentary rock.

Paleo-Puzzle Solutions

Solution I The skeleton was deposited on a fault line, or a fracture in the rock holding the dinosaur. A fault line is found where changes in the earth's surface have caused huge segments of rock beneath the surface to drop, lift, or slide away from each other. The rocks that were next to each other when the dinosaur remains were buried have moved. You will have to go hiking to find the dinosaur's head; the fault may have dragged it miles away.

Solution II These animals were so large that the extremities rotted away before the whole carcass could be buried by sediments. Complete burial of a sauropod could take several years!

Solution III There are several solutions to this puzzle. Large, adult bones fossilize more readily than small, delicate, juvenile bones. Quite simply, the remains of juvenile dinosaurs may not have a chance to fossilize. Another reason for the scarcity of young dinosaurs' remains is that young dinosaurs may have lived differently and in different places than their parents. For example, they may have lived in environments that did not lead to preservation.

Solution IV Mammals and birds stop growing at a certain point in their lives, well before they die. Reptiles do not stop growing; they become bigger and bigger until they die, though they grow very slowly at the end of their lives. Therefore, paleontologists cannot say that the remains they have found, even if they are the largest remains found to date, represent the limits of the dinosaur's full growth. Another dinosaur, whose remains have yet to be dug up, may have lived an easier, longer life, found more to eat, and may have grown even larger.

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ART TO ZOO brings news from the Smithsonian Institution to teachers of grades three through eight. The purpose is to help you use museums, parks, libraries, zoos, and many other resources within your community to open up learning opportunities for your students.

Our reason for producing a publication dedicated to *promoting the use of community resources among students and teachers nationally* stems from a fundamental belief, shared by all of us here at the Smithsonian, in the *power of objects.* Working as we do with a vast collection of national treasures that literally contain the spectrum from "art" to "zoo," we believe that objects (be they works of art, natural history specimens, historical artifacts, or live animals) have a tremendous power to educate. We maintain that it is equally important for students to learn to use objects as research tools as it is for them to learn to use words and numbers—and you can find objects close at hand, by drawing on the resources of your own community.

Our idea, then, in producing ART TO ZOO is to share with you—and you with us—methods of working with students and objects that Smithsonian staff members have found successful.

Many thanks to the following people at the Smithsonian for their help in preparing this issue of ART TO ZOO:

National Museum of Natural History: Laura McKie, Rebecca Mead, Raymond Rye and Hans-Dieter Sues

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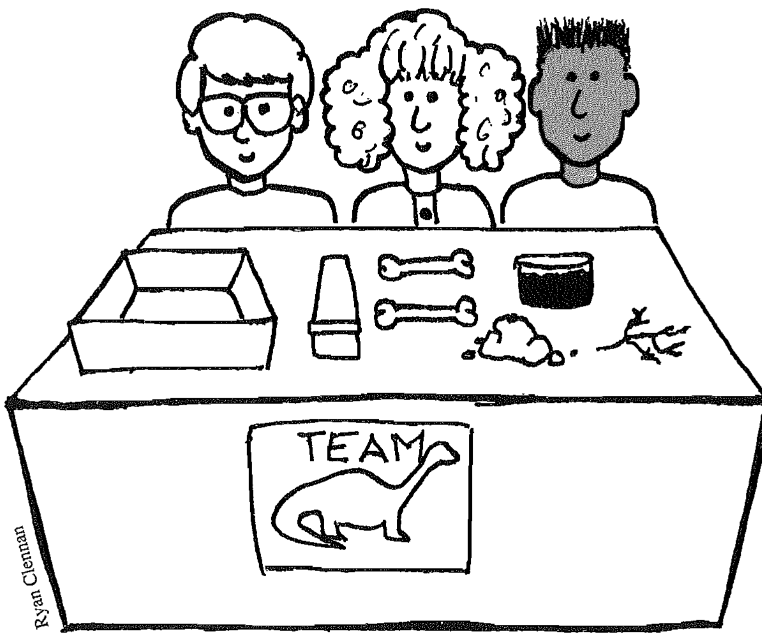
ART TO ZOO April 1992
News for Schools from the Smithsonian Institution

Fossil Finds...In the Classroom?



Now that you have learned about John Horner's maiasaur discovery and how paleontologists search for and interpret fossils, it is your turn to try the science. This Pull-Out Page invites you and your classmates to build a model of a fossil find.

Science is a collaborative activity. Scientists practice in groups as they collect, record, and interpret data. It is easy to understand why paleontologists work in groups. They benefit from each other's understanding, certainly. Also, it is nice to have fellow paleontologists nearby when you unearth a six-foot-long limb bone!

Form Your Paleontology Team

Join the classmates who will be members of your science team and tell them about the "favorite" dinosaur you studied in the Practicing Paleontology activities. Encourage your team to ask you questions about your dinosaur. When your group has heard about all the teams' dinosaurs, choose one that interests the group most. This dinosaur will be the one your team displays in the fossil find.

Give your team a name, to represent its personality, interests, and focus dinosaur.

Now your science team should learn as much about the dinosaur as it possibly can. Find out when and how long the dinosaur lived and where its remains have been discovered. What did the dinosaur look like?

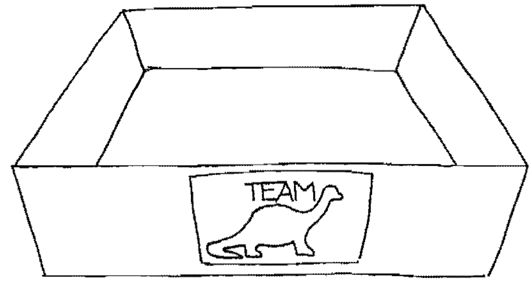
Crested or frilled? Horned or armor-plated? What shape print did its feet leave? If it was an herbivore, which plants did it eat? If it was a flesh-eater, which animals became its prey? Become hunters yourselves, hunters of materials to inform you about your dinosaur, beginning with library books.

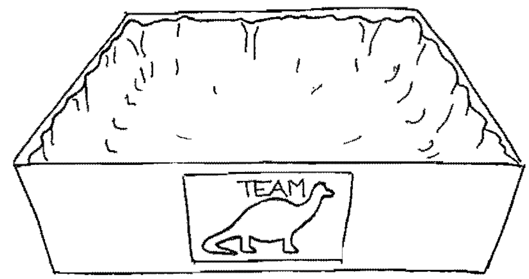
Record the knowledge you gain about your team's dinosaur in your field journal, the written account of the progress of your "expedition." The background information will be the first entry in your field journal. As you construct your site, you will note your findings, draw maps of the site, and make hypotheses about the fossils in the field. Read more about the field journal ahead.

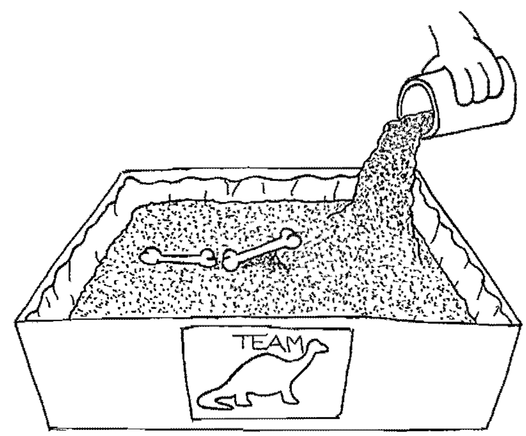
Gather Your Materials

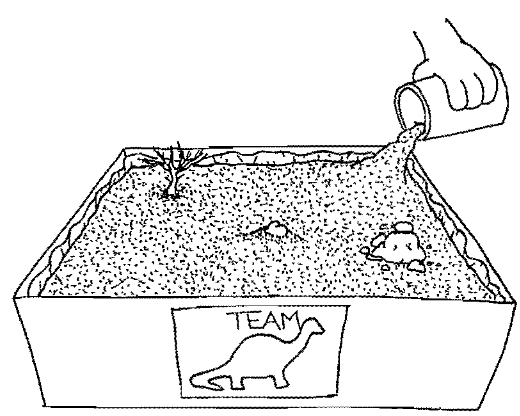
Your science team is going to build a miniature landscape that holds fossilized "dinosaur remains". . . right in your own classroom. This project will take some imagination. Your whole class will have to imagine that modern materials are really Mesozoic remains, that chicken bones are dinosaur bones, that sand scooped from the backyard sandbox was once the bank of a Late Triassic river. Imagination is a natural part of science; paleontologists rely on it to conceive of the world dinosaurs occupied so long ago. In addition to imagination, you will need:

- a large, strong cardboard box
- plastic for lining the box
- spray adhesive or spray acrylic glaze to keep the top layer of sand or soil in place
- soil of different colors and textures: sand, clay, topsoil or potting soil, and gravel
- plant leaves, seeds, stalks, or needles. Make plant fossils by pressing any part of a plant into plaster of Paris to make an impression. Then peel the plant matter away and let the impression dry. Or simply use the plant in









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your model to represent a plant fossil.

Learn which plant grew at the time and in the region your dinosaur lived. During dinosaurs' millions of years on earth, climate and plants changed greatly. The hot, dry Triassic Period supported evergreens and ferns. During the milder, wetter Jurassic Period, forests grew and became denser. The cooler, drier Cretaceous brought a range of new, flowering plants such as oaks and daffodils.

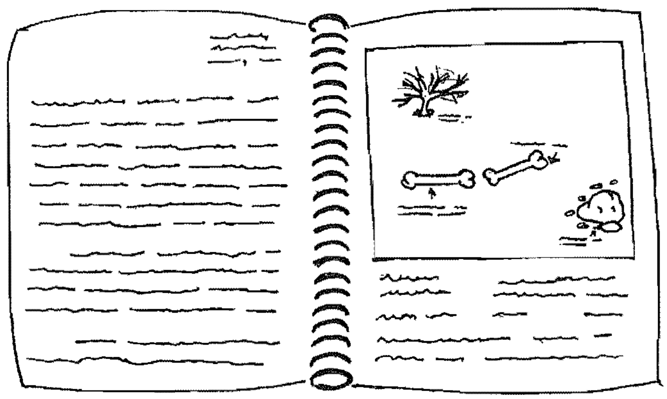
- ***Bones.*** No one in your science team has a pile of dinosaur bones in his or her basement. Because birds are the dinosaurs' closest living relatives, chicken bones are good substitutes Ask your parents to prepare a whole chicken for dinner, instead of cut pieces. Carefully clean the meat from the bones and learn about how the parts of the skeleton fit together Then use this skeleton for imitation dinosaur bones. Or make bones from modeling clay.
- ***Tracks.*** Make dinosaur footprints by pressing heavy cardboard footprint cutouts into wet soil to create a trackway. Build a *Maiasaur, Protoceratops,* or hypsilophodont nest using chicken eggshells or plastic eggs.

A final option: reconstruct an authentic site. If you learn about a site while doing research, try to duplicate that site, or part of it, in your box.

Build Your Fossil Find

Before your group decides how you will display your fossils, create a story to explain how the fossils arrived at the site. Write the story in your field journal. A sample background story: "We believe this *Edmontosaurus* died trying to defend itself from *Tyrannosaurus rex*. *Edmontosaurus* had been eating leaves from a magnolia tree that grew by the side of a fast-moving river. (We can tell this ancient river was fast-moving because the grain size of the matrix holding the remains is so tiny and fine.) After *Edmontosaurus* died, the fast waters picked up its body, rolling it over and over before depositing it in its burial place. We found foot bones, some plant remains, and a broken *Edmontosaurus* forearm bone (radius)." Your story will help you decide what to put in your fossil find.

Write in Your Field Journal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As professionals, do, your team will keep a field journal as a record of your excavation's progress. The journal should include hand-drawn maps of your site. If your site is based upon a real place, in your state or otherwise, copy or trace an authentic map of that place. If your team invents a site, draw in and name all the important topographic (surface) features of your site as they appear *before* you break ground, then as you dig. As your work proceeds, draw a picture of each fossil your team finds, and its position at the site.

Use your field journal as a science diary. Write a daily account of what your science team finds, describing what you find first, second, etc., the kind of rock your fossils are embedded in, the condition of the fossils. Mention any fossils you see. Write about how well or poorly the work is going. To make your field journal as authentic as possible, use scientific words as often as you can. For example, a real paleontologist calls a thigh bones the "femur." A list of useful words appears in the

Paleontology Lexicon (dictionary) on this page.

In many ways, this imaginary fossil find happens backwards. Real paleontologists free fossils from rock; your science team is covering "fossils" with dirt! Real paleontologists compose stories about what happened at their site *after* they dig up the bones; your science team created the story *before* assembling the site model. Real paleontologists jacket bones carefully and carry them away; you will leave bones exposed for your classmates to examine. But your purpose is the same as a real paleontologist's: to learn about prehistoric life by studying fossils.

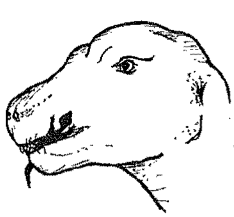
Present Your Fossil Find to Your Classmates

When you have completed your model and the accompanying field journal, present your find to your class. If your team wants to offer the class a chance to discover still-hidden remains, invite another science team to expose and analyze the fossils in your box. Or, your team could show the class fully exposed remains and ask for interpretations.

Paleontology Lexicon

Use these scientific words to discuss and write about your fossil find.

Articulated: joined or connected, pertaining to skeletons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Carnivore: a flesh-eating animal

Clutch: a nest of eggs

Coprolite: fossilized dung

Cranium: the part of the skull that covers the brain

Enamel: the hard outer covering of a tooth

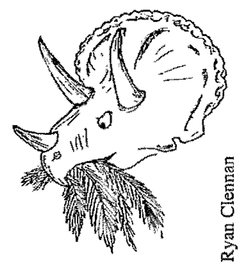
Femur: thigh bone

Fenestra: opening in a skull or other bone

Fibula: the narrower shin bone

Fossil: any evidence of life from the geologic past

Gastrolith: stomach stone or pebble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Herbivore: a plant-eating animal

Humerus: the upper arm bone

Keratin: a protein that makes feathers, claws, beaks, horns, hooves, and scales, as well as human hair and fingernails

Matrix: the rock surrounding a fossil

Nestling: a young dinosaur not yet ready to leave the nest

Preparator: a technician who removes fossils from rock matrix

Radius: a forearm bone

Sedimentary rock: rock formed by deposited particles; shale, sandstone, and limestone

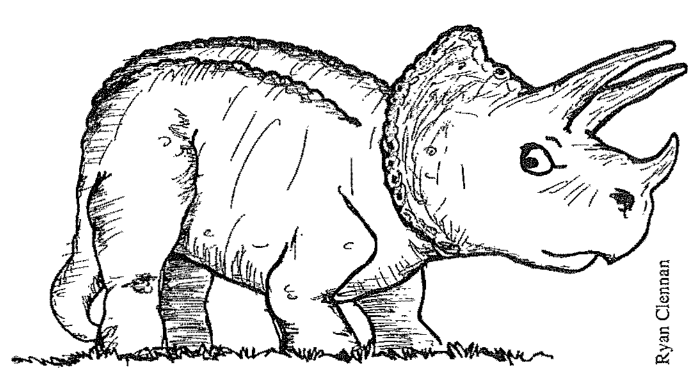
Scapula: shoulder blade

Tendon: the tissue that attaches muscle to bone

Tibia: the larger shin bone

Ulna: a forearm bone

Vertebra: a bone of the backbone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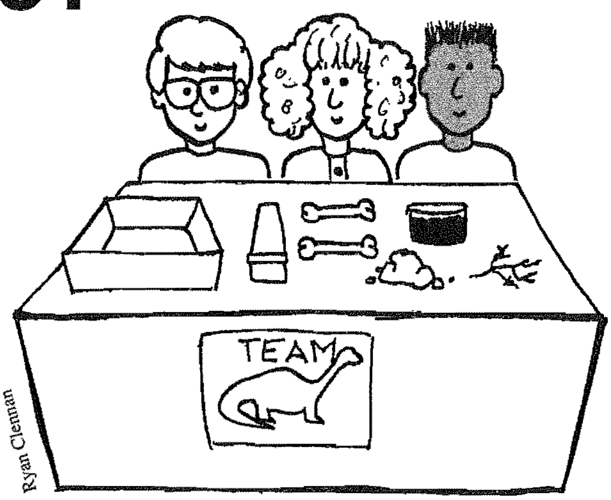
Del Arte al Zoológico Abril 1992
Noticias para las escuelas del Smithsonian Institution
Traducido por Maria del Rosario Basterra

¿Descubrimiento de Fósiles... en la Clase?



Ahora que has leído la historia del descubrimiento del maiasaurio de John Horner y aprendido acerca de como los paleontólogos investigan e interpretan fósiles, es tu turno de tratar de hacer lo mismo. Esta pagina de sacar, les invita a ti y a tus compañeros de clase a construir un modelo para la búsqueda de fósiles.

Ciencia es una actividad que se hace en colaboración. Los científicos trabajan en equipos cuando recolectan, codifican e interpretan información. Es fácil entender porque los paleontólogos trabajan en grupos. Ciertamente, se benefician del conocimiento de cada uno de sus compañeros. A su vez, es agradable tener a un compañero paleontólogo cerca cuando desentierras un hueso de una extremidad que mide seis pies de largo.

Organiza Tu Equipo de Paleontología

Reúne a los compañeros de clase que serán tus futuros miembros de equipo e informales acerca de tu dinosaurio "favorito" sobre el cual aprendiste en las Prácticas de Paleontología. Anima a tu equipo a hacer preguntas sobre tu dinosaurio. Cuando tu grupo haya oído acerca de los dinosaurios de todos los equipos, escoje el dinosaurio que le interese más a tu grupo. Este será el dinosaurio que tu equipo muestre en la busqueda de fósiles.

Dale a tu equipo un nombre que represente la personalidad, interés y caracteristícas más importante del dinosaurio que escogieron.

Ahora tu equipo científico deberá aprender lo más que pueda acerca del dinosaurio. Averigua hace cuanto tiempo existió este dinosaurio y cuantos años solía vivir, averigua tambien donde se descubrieron sus restos. ¿Cuál era la apariencia del dinosaurio?

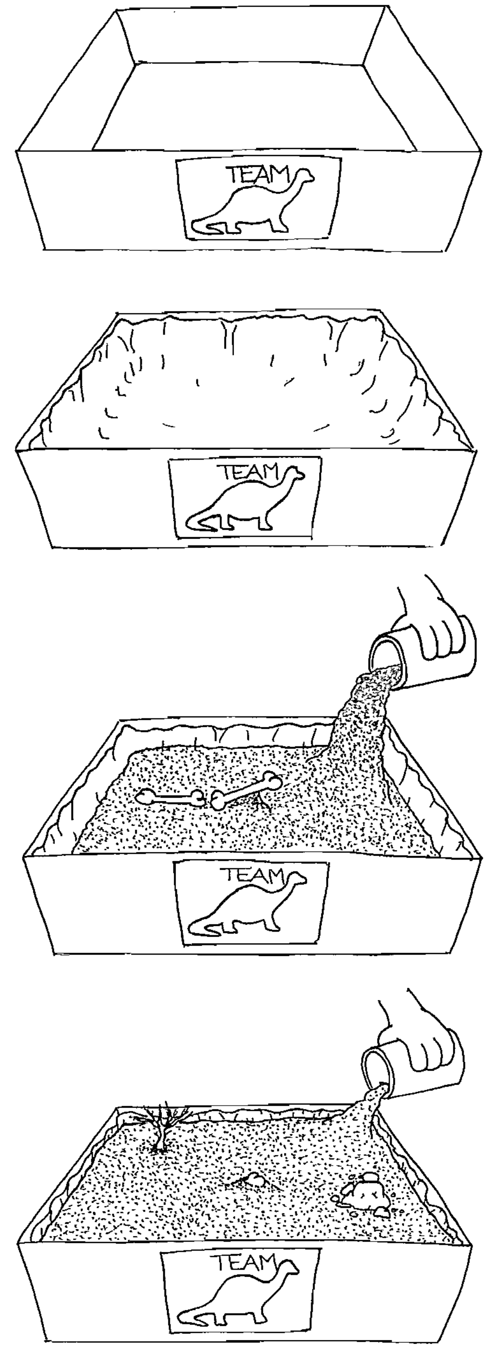
¿Tenía cresta o un cuello adornado? ¿Tenía cuernos o tenía la piel como un acorazado? ¿Qué tipo de huellas imprimían sus patas? Si era herbiboro ¿qué tipo de plantas comía? Si comia cárne, ¿qué animales eran sus presas? Conviértanse en cazadores, cazadores de información acerca del dinosaurio que han escogido, empezando por los libros de la biblioteca.

Anoten lo que van aprendiendo acerca de su dinosaurio en un diario, diario en donde irán anotando el progreso de su “expedición”. La primera entrada que incluirán en su diario sera la información basica sobre el dinosaurio. En la medida en que vayan construyendo su area de investigación, irán anotando sus descubrimientos, dibujarán mapas del área, y harán hipótesis sobre los fósiles que encuentren allí. Encontrarás mas información sobre tu diario más adelante.

Reúne Tus Materiales

Tu equipo va a construir un paisaje de miniatura que contiene “restos de dinosaurio fosilizados”...allí mismo en tu propia clase. Este proyecto requiere algo de imaginación. Tu clase tendrá que imaginar que los materiales de construcción modernos son realmente restos Mesozoicos, que huesos de pollo son huesos de dinosaurio, que la arena recogida de la caja de arena del patio fue alguna vez parte de la orilla de un ulterior río Triásico. La imaginación es parte natural de la ciencia; los paleontólogos se apoyan en ella para concebir el mundo que los dinosaurios habitaron hace mucho tiempo. Ademas de imaginación, necesitarán

- una caja de cartón grande y resistente
- plástico para forrar la caja
- roceador adhesivo o barniz acrílico para mantener la capa superior de arena o tierra firme



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- tierra de diferentes colores y texturas: arena, arcilla, tierra natural o comercial, y cascajo o arena gruesa
- piedras de varios tamaños
- hojas, semillas, tallos, u hojas aciculadas. Hagan fósiles de plantas imprimiendo cualquier parte de una planta en un molde de yeso para lograr una impresión. Luego saquen los restos de la planta y dejen que la impresión se seque. O simplemente usen las

plantas que tienen en su modelo de tal forma que representen fósiles. Averiguen que tipo de plantas existían en la epoca y región en la que vivió tu dinosaurio. Durante los millones de años en que los dinosaurios existieron, el clima y las plantas cambiaron significativamente. El caluroso y seco Período Triásico permitió el crecimiento de siempre verdes y helechos. Durante el templado y húmedo Período Jurásico, bosques crecieron y la vegetación se hizo mas densa. El frío y seco Cretáceo trajo un nuevo tipo de plantas tales como los robles y los narcisos.

- huesos. Nadie en tu equipo científico tiene una pila de huesos de dinosaurio en su zotano. Dado que los pájaros son los seres vivientes mas proximos a los dinasaurios, los huesos de pollo son buenos substitutos. Pídele a tus padres que preparen un pollo entero para cenar en vez de partes de pollo. Separa cuidadosamente la carne de los huesos y observa como las diferentes partes del esqueleto se juntan. Luego utiliza ese esqueleto como una imitación de los huesos de dinosaurio. O utilizen huesos hechos de arcilla tal y como hicimos en la Práctica de Paleontología Actividad 3.
- rastros. Fabriquen huellás de dinosaurio apretando recortes de huellas hechas con cartulina gruesa en tierra húmeda. Construyan el nido de un *Maiasaurio*, *Protoceratopo*, o hypsilophodonto utilizando cáscaras de huevos
- huevos de plástico.

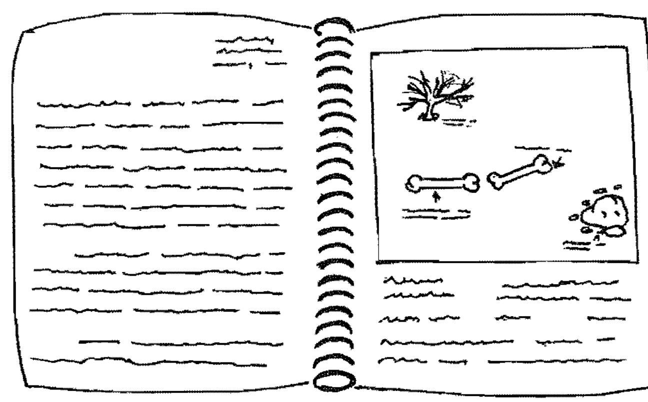
Una última opción: reconstruyan una área auténtica. Si descubren algun área mientras hacen su investigación, traten de reproducirla en su totalidad, o parte de ella en su caja.

Construyan un Modelo del Area del Hallazgo de Fósiles

Antes que el grupo decida como van a exhibir sus fosiles, inventen una historia que explique como los fosiles llegaron al lugar. Escriban la historia en su diario de investigación. Ejemplo de una historia: "Pensamos que este *Edmontosaurius* murió tratando de defenderse del *rey Tyrannosaurius.*

Los *Edmontosaurius* habían estado alimentandose de hojas de un árbol de magnolias que creció a la orilla de un río con un flujo de agua muy rápida. (Podemos decir que este río ancestral tenía un flujo rápido porque el tamaño del grano de la matriz que sujeta los restos son pequeños y finos.) Después que el *Edmontosaurus* murió, las rápidas aguas arrastraron su cuerpo, haciéndolo rodar una y otra vez antes de depositarlo en el lugar donde quedó enterrado. Encontramos huesos de pie, restos de algunas plantas, y un hueso roto de un radio (radius) del *Edmontosaurius*." Tu historia te ayudará a decidir que poner en su modelo.

Escriban en Su Diario de Investigación



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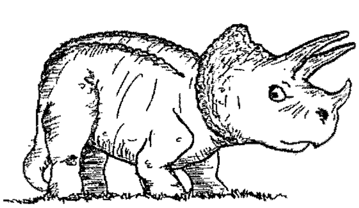
Tal y como hacen los profesionales, tu equipo mantendrá un diario de investigación como un record del progreso de sus excavaciones. El diario debera incluir mapas hechos a mano del área del hallazgo. Si su área está basada en algún lugar real, en el estado en donde vives o en otro sitio, copia o calca un mapa aunténtico del lugar. Si tu equipo se ha inventado el área, dibujen e indiquen la topografía (supericie) más importante tal y como aparecía *antes* que iniciasen la excavación, luego como se veía cuando excabavan. En la medida en que progrese su trabajo hagan dibujos de cada fósil que el equipo encuentre, y su posición en el area.

Usen su diario de investigación como un diario científico. Escriban los descubrimientos de su equipo diariamente, describiendo que encontraron primero, segundo, etc., el tipo de roca que cubría los fósiles, la condición de los fosiles. Mencionen cualquier fósil que vean. Describan lo bien o lo mal que esta yendo el trabajo. Para hacer su diario de investigación tan auténtico como sea posible, usen palabras científicas cada vez que puedan. Por ejemplo, un paleontólogo de verdad le llama "fémur" al hueso de la pantorrilla. Una lista de palabras útiles aparece en el Léxico de Paleontología (diccionario) al final de la página de sacar.

De muchas maneras, esta búsqueda imaginaria de fosiles sucede a la inversa. Los verdaderos paleontólogos remueven a los fósiles de las rocas; tu equipo científico ¡está cubriendo a los "fosiles" con tierra! Los verdaderos paleontólogos escriben historia acerca de lo que pasó en el area *después* que ellos desenterraron los huesos; tu equipo científico creó la historia *antes* de construir el modelo. Los verdaderos paleontólogos cubren los huesos cuidadosamente y se los llevan; ustedes dejarán los huesos expuestos para que tu clase los pueda examinar. Pero su propósito es el mismo que el de los verdaderos paleontólogos: aprender sobre la vida prehistórica estudiando fosiles.

Presenta tus Fósiles a tus Compañeros de Clase

Cuando hayan acabado su modelo y el diario científico, hagan una presentación de sus fósiles a la clase. Si tu equipo quiere ofrecerle a la clase la oportunidad de descubrir algunos restos adicionales, inviten a otro equipo científico a presentar y analizar los fósiles de la caja. O, tu equipo podría mostrarle a la clase todos los hallazgos y pedir interpretaciones a los compañeros de clase.



Ryan Clennan

Léxico Paleontológico

Usen estos terminos científico para discutir y escribir acerca de los fósiles descubiertos.

Articulados: unidos o conectados, perteneciente a esqueletos

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Carnívoro: un animal que come carne

Nidada: un nido con huevos

Coprolito: excremento fosil

Craneo: la parte osea que cubre el cerebro

Enamel: la parte dura que cubre los dientes

Fémur: hueso de la pantorrilla

Fenestra: orificio en el cráneo u otro hueso

Peroné: hueso angosto de la espinilla

Fósil: cualquier evidencia de vida del período geológico

Gastrolito: piedra del estómago

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Herbívoro: un animal que come plantas

Húmero: el hueso de la parte superior del brazo

Queratina: proteína que se encarga de producir plumas, harras, picos, cuernos, cascos y escamas, y tambien pelo humano y uñas

Matriz: la roca que rodea un fosil

Polluelo: un joven dinosaurio que todavía no esta listo para abandonar el nido

Preparador: tecnico que remueve fosiles de la roca matriz

Radio: hueso del antebrazo

Roca sedimentaria: roca formada por particulas depositadas; esquisto, piedra arenisca y piedra caliza

Escápula: omoplato

Tendón: el tejido que adhiere el musculo al hueso

Tibia: hueso alargado de la espinilla

Cúbito: hueso del antebrazo

Vertebra: hueso del espinazo