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FOSSIL MATERIALS? Careful Metalworking Brings Dinos to Life

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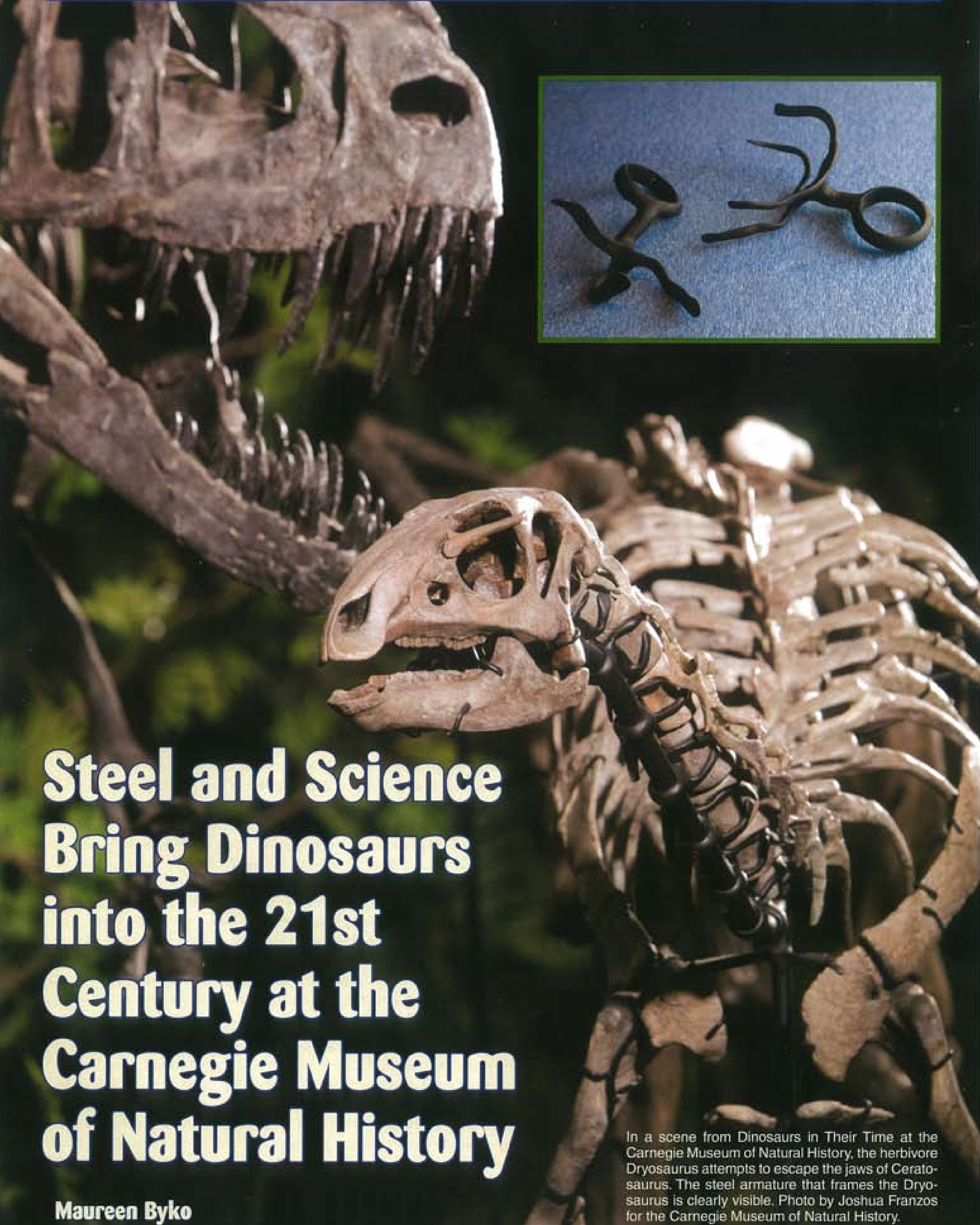

Steel and Science Bring Dinosaurs into the 21st Century at the Carnegie Museum of Natural History

Maureen Byko

In a scene from Dinosaurs in Their Time at the Carnegie Museum of Natural History, the herbivore Dryosaurus attempts to escape the jaws of Ceratosaurus. The steel armature that frames the Dryosaurus is clearly visible. Photo by Joshua Franzos for the Carnegie Museum of Natural History.

Enhanced for the Web

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INTRODUCTION

For 60 years, a Tyrannosaurus rex stood tall in the Carnegie Museum of Natural History, its ancient bones posed awkwardly erect, more like a sharp-toothed kangaroo than a tyrant lizard king.

The display made sense to paleontologists when it was erected. But science has changed and so, in response, has the Carnegie. The Pittsburgh, Pennsylvania museum this month will complete a massive renovation of its dinosaur exhibit—the third-largest in the United States. Over the last three years, skeletons large and small have been disassembled, cleaned, and rearticulated into poses that reflect current theory. And to pique the imaginations of young dinosaur lovers, the skeletons are arranged to suggest predator-versus-prey storylines.

With the opening of the completed Dinosaurs in Their Time exhibit, this month, the once-towering T. rex will be seen crouching low, neck practically parallel to the ground, ready for a Cretaceous period showdown with another T. rex (Figure 1). Over in the Jurassic section, which opened with the exhibit's first phase in November, the stately Apatosaurus cranes its long neck gracefully backward, (Figure 2) facing a predator that seems to be closing in (Figure 3).

To be sure, the stars of the $36 million restoration are the Carnegie's renowned collection of fossils. But the supporting players, unnoticed and yet essential to the drama on the museum floor, are the steel armatures that encase them. The handcrafted frameworks allow the T. rex to crouch low, ready to fight. They raise the Diplodocus tail off the ground and support its unwieldy neck. And yet, the general public is unlikely to appreciate this one-of-a-kind hardware. That, says Matt Lamanna, the museum's assistant curator of vertebrate paleontology, is the sign of expert dinosaur mounting. "There is such

Figure 1. In an exhibit still under construction, two T. rexes extend their backs parallel to the ground instead of upright. When complete, the exhibit will include vegetation and other creatures from the Cretaceous Period. Photo by Joshua Franzos for Carnegie Museum of Natural History.

Figure 2. The Diplodocus carnegii, left, and Apatosaurus louisae, right, tower over visitors in Dinosaurs in Their Time at the Carnegie Museum of Natural History. Diplodocus and Apatosaurus were discovered in 1899 and 1909, respectively. Diplodocus carnegii is named after Andrew Carnegie, while Apatosaurus louisae is named after Carnegie's wife, Louise. Photo by Joshua Franzos for Carnegie Museum of Natural History.

Figure 3. The re-articulated Allosaurus was unveiled in November 2007 in the completed first phase of the Carnegie exhibit. The second phase, opening June 15, will complete the $36 million dinosaur exhibit renovation. Photo by Joshua Franzos for Carnegie Museum of Natural History.

attention to detail that a lot of people don't even see the armatures. That's the beauty of it," he said.

DECONSTRUCTING DINOSAURS

Before he ever accepted the job overhauling the Carnegie's fossils, Phil Fraley, founder of Phil Fraley Productions, was well aware of the museum's legendary dinosaur hall. "Their collection is actually the best collection in the world of Sauropod dinosaurs," he said. "For me it was a dream come true to be able to work with the Carnegie Museum on this collection." This from a man who'd worked on such high-profile projects as the dinosaur hall restoration at the American Museum of Natural History in New York City and the installation of Tyrannosaurus Sue at the Field Museum in Chicago.

The Pittsburgh exhibit would be his company's largest yet. The Carnegie update would more than triple the size of the museum's dinosaur hall, grouping the fossils according to the period in which they lived, surrounding them with an approximation of the plant life of that time, and posing the bones to reflect new thoughts on dinosaur biomechanics. This would be the largest renovation since the museum opened in 1895, and Fraley was eager to be a part of it. *[Read* JOM *on-line to access videos of the renovation process.]*

Of course, the primary goal was to make the skeletons more scientifically accurate. "Science is sort of a successive approximation of the truth," Lamanna said. The truth as it was known when the T. rex's upright posture was determined is different than the truth of today. Another goal, though, was to imply action with enough color and drama to enthrall modern-day museumgoers. That was where the art of metalworking was essential. When molded expertly, the steel framework brings an organic quality to the fossils, Fraley said. "Really, what an armature is doing is replacing all the tendons and ligaments—the soft tissue that used to hold the animal together," he said.

The ten skeletons Fraley's team would work on had their own armatures already, and some had been standing for 100 years. That made the first step in the project—dismantling the existing structures for shipment to Fraley's New Jersey workshop—a slow-going affair. The oldest specimens, the Diplodocus carnegii and Apatosaurus Louisae, both date back to the early 1900s. (See the sidebar for details on the early days of the Carnegie exhibit.)

Among the concerns at the outset were the safety of workers—the pelvic bones of those large specimens weigh more than 3,000 lb, Fraley said. And they had to worry about protecting the

ANDREW CARNEGIE—BUILDING A LEGACY IN STEEL AND STONE

Thanks to the passion for paleontology of its wealthy namesake, the Carnegie Museum of Natural History displays more fossilized dinosaur bones than any other museum in the United States except the Smithsonian National Museum of Natural History in Washington, D.C., and the American Museum of Natural History in New York. The museum's current status as a leader in paleontology began in 1898, when Andrew Carnegie organized the museum's first dinosaur expedition to Wyoming. Carnegie, the Pittsburgh industrialist whose name is emblazoned on cultural centers such as libraries and performance halls well beyond the Pittsburgh borders, had earned his fortune in the steel industry when he set his mind to adding dinosaurs to his namesake museum. According to the museum, he learned that archeologists had discovered some ancient bones in Wyoming, and promptly sent a team to the area. In 1899 they discovered the toe bone of an unknown creature, and when the full skeleton was collected and returned to Pittsburgh, the museum's paleontologist named it Diplodocus Carnegii, after Carnegie.

The find became the first of several holotypes—the original specimen of a species—in the Carnegie collection. Carnegie's team a few years later unearthed a trove of Jurassic-era bones in Utah and sent the bones back to Pittsburgh for identification, preservation, mounting, and finally display to the public. Among the finds were Apatosaurus louisae, the holotype of that species, Camarasaurus, Stegosaurus, Dryosaurus, the Camptosaurus

Figure A. The Carnegie Museum of Natural History's team of conservators in 1903. Photo courtesy of the Carnegie Museum of Natural History.

Figure B. The Allosaurus in its original pose. Photo courtesy of the Carnegie Museum of Natural History.

specimens as well, lifting the bones without stressing them. He had no idea until the work was begun the condition of either the metal or the fossils, and there were some surprises.

"The armatures for the Diplodocus and the Apatosaurus were really under-built," Fraley said. Over the decades shifting occurred. Two vertical supports under the pectoral girdle and the shoulder of the Apatosaurus, meant to share the weight of the structure equally, had spread over the years, three and a half inches in each direction. "They were no longer plumb," Fraley said. "They were going in opposite directions." The separation was caused by a combination of the weight of the specimen and the likelihood that the skeleton was moved at some point without people taking proper precautions to stabilize it. In addition, during the disarticulation of the Apatosaurus, Fraley's team found that metal plates that had been bolted onto the pelvis had stress fractures in two places. "That was a pretty dangerous situation for the specimen," Fraley said. "Had there been a sudden jolt that would have caused this to move in one particular direction, there was a high probability that it would have broken," and with potentially disastrous consequences, he added.

Damage was also caused by what Project Manager Larry Lee described as "metallurgical mistakes." In particular, a galvanic effect resulted from welds of cast steel to cast bronze. "It kind of diseased those metals," he said. Lee found evidence of those poorly planned welds in the T. rex and the Allosaurus, where bronze was used in the underside of some vertebrae to create a seat that would hold the bone in position. The bronze-steel welds held up, Lee noted, but the metal was deteriorated. Needless to say, no bronze mounts were used when Fraley's company reconstructed the dinosaurs. Instead, new steel cradles were made individually to fit each vertebra of the dinosaurs. And, in Lamanna's eyes, those cradles were more than steel supports. "Each cradle is a customized work of art that keeps the specimen safe," he said.

21st CENTURY DINOSAURS

There may have been flaws in some of the original dinosaur mounts, but there was also a level of artistry that surprised Fraley and Lee. On the Apatosaurus and Diplodocus, in particular, the armatures were unique, Lee said, made of cast steel underneath the vertebra to create a support system.

Lee first worked with Fraley in the 1990s at the American Museum of Natural History in New York. There, Lee said, the vertebrae were supported not by cast steel but instead a series of saddles fitted onto a horizontal steel round.

holotype, and Allosaurus. In 1941, the museum continued its tradition of acquiring prized specimens by purchasing the Tyrannosaurus rex holotype. The Cretaceous period carnivore stood alone in the dinosaur hall since then, but in June will be joined by another T. rex, this one a cast rather than original fossil.

When Carnegie began collecting dinosaur skeletons, their display was a relatively new art in the early 20th century, said Phil Fraley, whose company recently remounted ten of the museum's dinosaurs. "At that point in time paleontology was in its infancy as a science," he said. But Carnegie's newly assembled team of preparators did a long-lasting job of shaping steel to fit the bones (Figures A–D) and they used a top quality steel, said project manager Larry Lee.

"We did a metallurgical analysis of it and found it was an excellent mild steel," he said. "We were able to TIG-weld with it, bend it, drill it, and tap into it—it had excellent qualities. They used excellent iron in their castings. We really lucked out." For that reason, some of the oldest mounts were able to be reused and built upon, Lee said.

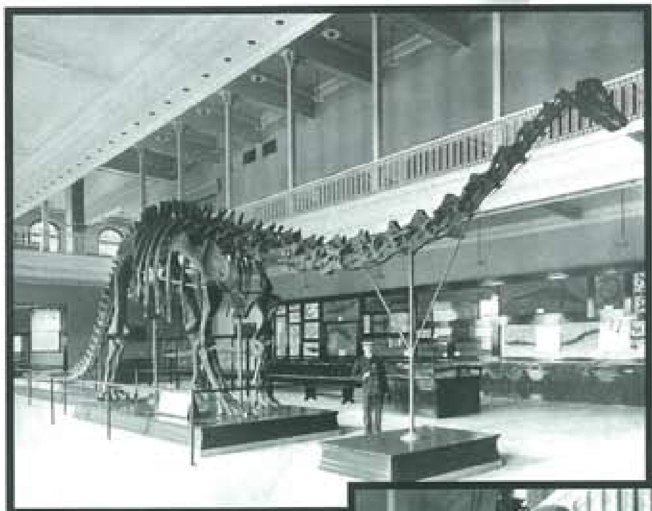

Figure C. Diplodocus carnegii, the museum's first major dinosaur. Photo courtesy of the Carnegie Museum of Natural History.

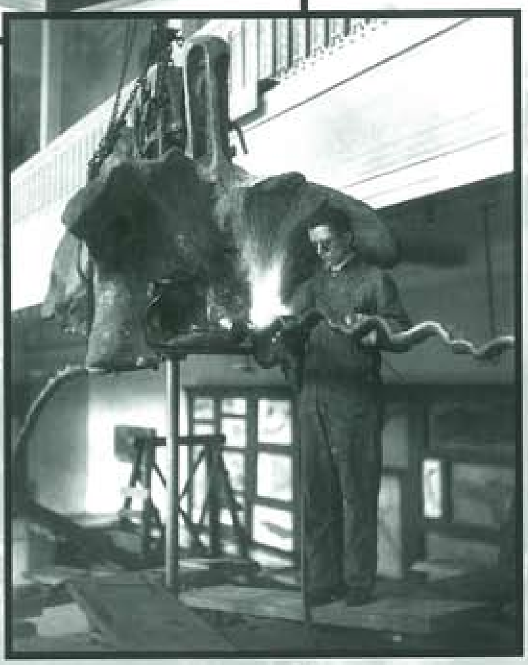

Figure D. An unidentified worker custom shapes an armature. Photo courtesy of the Carnegie Museum of Natural History.

Figure 4. Lead fabricator Paul Zawisha attaches a cast of the upper pelvis of a T. rex to a metal armature while fabricator Donna Lopp bends a piece of metal tubing that will become the armature for a section of the spine. Photo courtesy of Phil Fraley Productions.

Figure 5. Bob Zeller and Paul Zawisha attach dorsal ribs of the holotype T. rex to the armature during installation at the Carnegie Museum of Natural History. Building the armature took over nine months. Installing it on site took a little under four weeks. Photo courtesy of Phil Fraley Productions.

Figure 6. Looking straight up under the chin of the holotype T. rex. Only about half of the holotype T. rex's skull was ever found, so the 1926 mount used a reconstruction made from plaster and a good dose of imagination. Since then, many good specimens of T. rex skulls have been found. This new skull is a composite made of plastic casts molded from the genuine fossil fragments of the holotype combined with pieces from four other T. rex skulls. Photo by Joshua Franzos of the Carnegie Museum of Natural History.

Each of the saddles was created to hold a vertebra, Lee said. At the Carnegie, later dinosaur armatures were similarly constructed.

Those early castings were so unique that Fraley reused them in the new display. "We couldn't do a better job than what they had done in casting those ourselves," he said. "In some ways it was our way of recognizing and appreciating the work that all these men a hundred years ago had done on the specimen. They were part of that specimen's history, and we're now a part of that specimen's history."

A BONA FIDE HIDDEN METALS CRAFT

Lee's background was in sculpture, particularly lost wax bronze casting and metal sculpting, when he turned his talents to dinosaur armatures. As he explored the workshops of the American Museum, he found remnants of the craftsmen who came before him. "I discovered this whole tradition of metal mount-making for dinosaurs. It included casting and blacksmithing, machining, all kinds of bending, all kinds of metal work. I discovered this bona fide hidden metals craft—a tradition that started with the folks at the Carnegie and at the American Museum at the turn of the 20th century."

Remounting dinosaurs at the Fraley studios extends that tradition (Figures 4–6). Once the skeletons have been painstakingly disassembled, the bones are stripped of all adhesives, paints, and shellacs layered on over the years to hide flaws. Then, for the larger pieces, such as femurs, the artisans make a cast so they can use those shapes without damaging the actual bones. The steel armatures are shaped while hot on the cast. For the smaller pieces, Lee said, "It's a process of bending steel with heat, then cooling the steel, and then checking it to see how close it is to the shape we want to achieve. It's rather painstaking: heating, bending, cooling, and comparing, and on and on, to make these custom fittings. It's a process akin to jewelry making. You take a precious stone and make a setting for it—that's what we're doing."

Maureen Byko is managing editor of *JOM*.