DINOSAUR MOTION

Did Saurian Predators Fold Up on Turns?

Want to run like a dinosaur? Step into David Carrier's lab at the University of Utah, Salt Lake City, and strap yourself into his dino-suit. With 2 meters of weighted planks balanced on your hips, you'll get a feel for how a carnivorous dinosaur called a theropod might have maneuvered its stretched-out frame.

Carrier's team has already strapped several students into the contraption and put them through their paces. Their conclusion: Large Mesozoic predators weren't track stars. In an upcoming issue of the *Journal of Experimental Biology*, Carrier and graduate students Rebecca Walter and David Lee argue that massive tails and bulky heads would have kept theropods from turning on a dime—and that could have made rugged terrain inaccessible or hindered their ability to catch prey. Other experts aren't so sure, noting that theropods excelled as top predators for 120 million years and differed from their human stand-ins in key ways. But even skeptics say that Carrier's creative approach to dino motion has given them things to consider. "This is one of those bits of incredibly delightful goofiness that I wish I'd thought of," says Jim Farlow, a paleontologist at Indiana University–Purdue University, Fort Wayne.

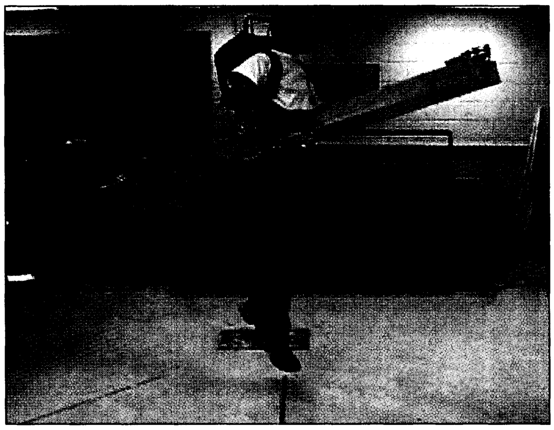
Carrier, a comparative physiologist, suspected that rotational inertia might have caused problems for theropods. When a graduate student joked about testing the idea by dressing up like Barney, a purple dinosaur on a children's TV show, Carrier immediately hit on an idea: Design a pack that would give a person the mass distribution of a similar-sized theropod. He and his crew measured the rotational inertia of a small plastic toy model of *Allosaurus*, then scaled it up to a 90-kilogram human. By constructing a backpack with horizontal beams jutting fore and aft, they increased the rotational inertia more than ninefold, into theropod territory.

The first test was to turn while jumping up in the air, à la basketball star Michael Jordan. Five grad students recruited from the biology department found that they could twist only 20% as far as when they jumped while wearing control backpacks with weights close to their backs. Next, nine grad students ran at top speed through a flat slalom course of six 90-degree turns. Their average velocity dropped to 77% of control runs. When the students had to place their feet in particular spots—to mimic turning on rough ground—their time fell to 65%. "It makes a tremendous difference," Carrier says. "As soon as you put the pack on, you're clearly compromised."

Large theropods would have suffered even more, Carrier says. Rotational inertia increases much faster than muscle strength as animals get larger, increasing the chance of stumbling, among other liabilities. "Those animals would have a hard time changing directions," Carrier says, "and the problems would have gotten worse and worse as they got bigger."

Faced with such challenges, Carrier suggests, theropods compensated by repeatedly evolving shorter tails, smaller bodies, porous vertebrae, and even fewer teeth. More controversially, Carrier and his colleagues propose that theropods rarely walked or ran with their trunks and tails horizontal, as most paleontologists imagine. Instead, the Utah scientists envision the back arched, tail raised high, and forelimbs tucked back against the body. This jackknife posture would reduce rotational inertia by half, they say.

Not everyone is ready for such an about-face. "It's a completely impractical way of walking," says dino-locomotion expert Don Henderson of Johns Hopkins University in Baltimore. The proposed posture, he argues, would reduce the mechanical advantage of the caudifemoral muscle, which attached to the tail and helped power the legs. Several other features of large theropods would have helped them deal with their rotational inertia, he says. Large toes and broad feet provided added leverage to tilt the body, and weight concentrated over the hips kept them relatively more compact than smaller dinosaurs.



New twist. Experiments with a weighted frame show that some large dinosaurs had trouble turning.

And then there's the tail. Farlow points out that theropod tails, unlike lumber, could bend. Used as counterweights, he says, tails could have helped the dinosaurs tack more sharply. Carrier concedes that the tail is important—he decided not to rig up a motor-driven tail to prevent injuries—but says that it would have helped a dinosaur reorient its head by less than 60 degrees. Despite qualms, some other heads are beginning to turn. "They've made a good first stab at estimating turning performance," says John Hutchinson, a graduate student studying theropod locomotion at the University of California, Berkeley. "That's a step forward." –ERIK STOKSTAD

PALEOECOLOGY

How Grasses Got the Upper Hand

A slow dwindling of carbon dioxide in the atmosphere during the past 100 million years is the common explanation for the sudden worldwide surge in the abundance of tropical and subtropical grasslands 7 million or 8 million years ago. As CO_2 levels slid below a critical threshold in the late Miocene epoch, the story goes, tropical grasses seized the ecological advantage from shrubs and trees because the molecular machinery by which grasses photosynthesize is particularly well adapted to taking up the essential gas at low levels. The rise of the grasses might then have driven the evolution of hoofed mammals well adapted to graze on them.

But loose ends keep appearing. The latest, as reported on page 1647 of this issue, points to moisture, not just CO_2, as pivotal in the emergence of low-latitude grasslands. It also clouds the crystal ball for researchers trying to get a handle on future global change.

The new study, by organic geochemist Yongsong Huang of Brown University in Providence, Rhode Island, and colleagues, compares the relatively recent ecological histories around two lakes to see which plants gained the upper hand. Since the peak of the last ice age, the two regions have experienced the same increase in atmospheric CO_2 levels but very different climate changes.

One of the two lakes, Alta Babícora in the northern Mexico state of Chihuahua, was brimming with water 13,000 to 21,000 years ago, judging by microfossils found in a mud core recovered from the lake bottom. From the same mud, Huang and his colleagues isolated distinctive long-chain hydrocarbons derived from the leaf wax of land plants carried into the lake. By measuring the carbon isotopic composition of these leaf hydrocarbons, they were able to gauge the ratio of land plants like shrubs and trees to tropical grasses.

The tropical grasses tend to use a different photosynthetic process: the so-called C_4 pathway rather than the C_3 pathway. It's the C_4 pathway that lets grasses concentrate CO_2 within their cells and outcompete C_3 plants for this essential compound. As a result, C_4 plants also produce organic matter richer in the heavier carbon isotope than do shrubs and trees. About 18,000 years ago, a relatively wet climate around Alta Babícora supported a

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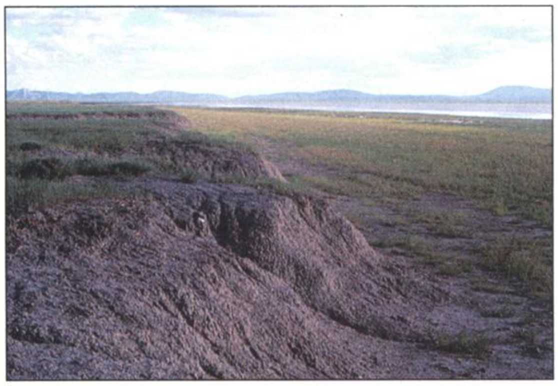

Molecular herbarium. Specific plant-leaf molecules preserved in the bottom muds of this Mexican lake recorded a shift toward grasses since the last ice age.

predominance of C_3 plants, according to the carbon isotopic analysis of leaf wax hydrocarbons. But after the end of the last ice age, weather patterns shifted, the lake level fell—reflecting a drying of the region—and C_4 plants such as grasses came to predominate.

More than 2000 kilometers to the southeast, under the same declining CO_2 levels, the postglacial weather shift tended to make the region around Lake Quexil in Guatemala wetter rather than drier. As the region moistened, the C_3 plants that had held a slight edge over C_4 grasses rose to an "overwhelming predominance," according to Huang and his colleagues. The two sites experienced the same change in CO_2 levels, but the C_4 pathway that gives an advantage to grasses under low CO_2 levels can also give them an edge in a drier climate, which turned out to be decisive at the drying Alta Babícora.

Huang extrapolates from the important role of climate 20,000 years ago to explain what might have happened in the Miocene 5 million to 20 million years ago. Although C_4 photosynthesis no doubt evolved in response to the long-term CO_2 decline during the past 100 million years, argues Huang, "to say CO_2 is the only driver [in the Miocene] for C_4 expansion is probably not correct. Low CO_2 [levels were] not enough. Aridity probably was also very important."

Geochemist Jay Quade of the University of Arizona in Tucson agrees that "CO_2 is not the only explanation" for the Miocene shift to C_4 grasses. Quade was one of the authors of the 1997 *Nature* paper by geochemist Thure Cerling of the University of Utah in Salt Lake City and colleagues that proposed the CO_2 decline as the proximate cause of the global expansion of C_4 grasses. The postglacial shifts found by Huang and colleagues are "pretty robust," Quade says, and they stress "the complexity of the control" of C_3 or C_4 dominance. Whether climate or CO_2 is foremost "is a matter of emphasis," he says.

The complexity of other aspects of the grasslands story has increased lately as well. Paleoceanographer Mark Pagani of Colorado State University in Fort Collins points out that recent analyses of records of Miocene CO_2—his own study of marine organic matter as well as research on sedimentary boron and the abundance of fossil leaf pores—suggest that CO_2 levels were already low by the time of the Miocene and did not decline markedly during that epoch. And paleontologist Christine Janis of Brown says that her recent work with colleagues on the fossil record of mammals that browsed on C_3 vegetation versus those that grazed on C_4 grasses isn't consistent with the theory that the shift to C_4 grasses triggered a burst of mammal evolution, at least not in North America. Their analysis of the fossil record shows that the major shift from mostly browsers to mostly grazers had already occurred there by 10 million years ago, well before the sudden expansion of grasslands 8 million years ago.

With atmospheric CO_2 levels now on the rise, such complexities could make it harder for scientists to predict which regions will have the greener pastures in the centuries to come. –**RICHARD A. KERR**

SCIENCE ON THE INTERNET

Mysterious E-Photos Vex Paleontologists

A dinosaur with a strange, bristly tail set paleontologists abuzz last week after grainy photographs of the fossilized creature began crisscrossing the Internet. Scientists yearn to know more about the fossil—which may have been smuggled out of China—and examine the specimen firsthand. But the tantalizing e-mail attachment said nothing about its whereabouts, and the few who know aren't telling. "It's not how I want to do science," says a frustrated Larry Witmer of Ohio University College of Osteopathic Medicine in Athens.

Sneak preview. Unauthorized photos of mystery fossil (*top*) inspired illustrations of bristle-tailed psittacosaurs in a new book.

The beast in question is a psittacosaur, a primitive horned dinosaur that grew to between 1 and 2 meters long. What makes this specimen unique is a tuft of what look like long, hairlike filaments on the end of its muscular tail. The significance of the filaments is not clear, but at their most profound they might represent an ancestral characteristic of all dinosaurs. "If it's real it would be very unusual and interesting," says Luis Chiappe of the Natural History Museum of Los Angeles County.

Speculation began around 20 August, when Michael Schmidt, a fossil dealer in Edmonton, Alberta, forwarded color photos of the specimen to some members of the DINOSAUR Internet mailing list. Schmidt says he obtained the pictures from a partner in France who knows both the buyer and seller and who wants to remain anonymous.

Paleontologists are viewing the fossil cautiously in light of doctored specimens that have been illegally exported from China in the past, such as *Archaeoraptor* (*Science*, 22 December 2000, p. 2221). The psittacosaur appears to have come from western Liaoning Province in China, an area with a wealth of feathered dinosaurs and other exquisitely preserved fossils about 125 million years old (*Science*, 12 January, p. 232). Paleontologist Zhou Zhonghe of the Institute of Vertebrate Paleontology and Paleoanthropology in Beijing believes that the psittacosaur was smuggled out of China a few years ago. Apparently, the specimen was prepared in an Italian museum, but negotiations to return it to China broke down, Zhou says. It's now rumored to be in a German museum.

Probably because of its shadowy history, no researcher has formally described, or even announced, the specimen at a conference or in the literature. Photographs surfaced a few years ago at a meeting of the Society of Vertebrate Paleontology but were only shown discreetly to a few people in the hallways. One of the viewers, paleoartist Luis Rey of London, included the hairy tail in his illustrations of psittacosaurs in *Extreme Dinosaurs*, a book published this month. "I'm trying to call attention to this specimen, to see if we can release it from its jail," Rey says. "It's such an important specimen, and we can't see it except as clandestine material."

Paleontologists who are now seeing the photos for the first time are exasperated. "All we have are pixely JPEGs that we're all trying to zoom in on and not seeing anything," Witmer says. But until the mysterious fossil comes to light, he says, all he and his colleagues can do is try not to think about it.

–**ERIK STOKSTAD**

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