Warmed-Over Dinosaurs

Paleontologists are still arguing whether dinosaurs, like birds and mammals, generated their body heat internally

BY JULIE ANN MILLER

Narrow width of tracks indicates dinosaurs walked with an upright gait. Both a sauropod and a three-toed flesh-eating dinosaur (footprints at left) traveled this trail near Glen Rose, Texas.

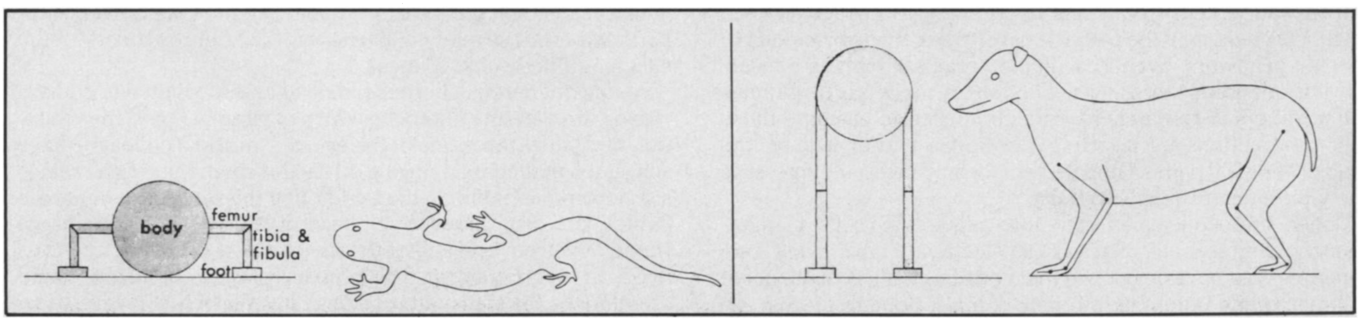
Roland T. Bird, Natural History (1944)

Fossils and footprints are difficult substitutes for body temperatures, blood pressures and basking behavior, but they must suffice in investigations of how dinosaurs controlled their internal temperature. Lack of direct evidence, however, can lead to differences of opinion, as is the case in one ongoing debate. Robert T. Bakker of Johns Hopkins University excited dinosaur fanciers a few years ago with an image of frolicking, warm-blooded giants instead of lumbering, oversized lizards. Despite Bakker's efforts, not all researchers are convinced. Some still hold to the cold-blooded theory. Others think different dinosaurs had different heating mechanisms. At the meeting of the American Association for the Advancement of Science in Washington (SN: 2/25/78, p. 116), a group of paleontologists gathered to take a cold look at what John H. Ostrom of Yale University calls "a somewhat over-heated debate."

Although the debate is often summarized as "cold-blooded" versus "warm-blooded," the controversy does not focus solely on the temperature of the animals' blood. Participants in the debate generally agree that for evolutionary success the larger the animal, the more likely that its body temperature is relatively high and constant (a state known as homeothermy). What is at stake in the controversy is the source of the heat. Large animals cannot afford to spend every morning warming up on a sunny rock. Did the dinosaurs, like lizards, use primarily external sources (ectothermy) or did they, like birds and mammals, use primarily internal metabolism (endothermy)?

With persistence and imagination scientists have found in fossils and footprints considerable ammunition to defend their theories. Some of the arguments are strictly correlative. For example, among currently living vertebrate animals, only endotherms stand and walk erect. The narrow width of all known dinosaur trackways from hundreds of sites around the world indicates an upright gait, Ostrom says. Shapes of fossil limb bones and hip and shoulder sockets also suggest that most dinosaurs held their limbs in a near-vertical position, rather than in the sprawling posture of lizards and other living ectotherms. "We simply do not know, as yet, whether erect posture can be achieved by an ectotherm," Ostrom explains. "No cause and effect has been found, but it [upright posture and endothermy versus ectothermy and sprawling posture] is an absolute correlation."

Endothermy, with its fast metabolic rate, requires high blood pressure and rapid circulation to provide adequate exchange of food and waste substances, according to another anatomical argument. Several



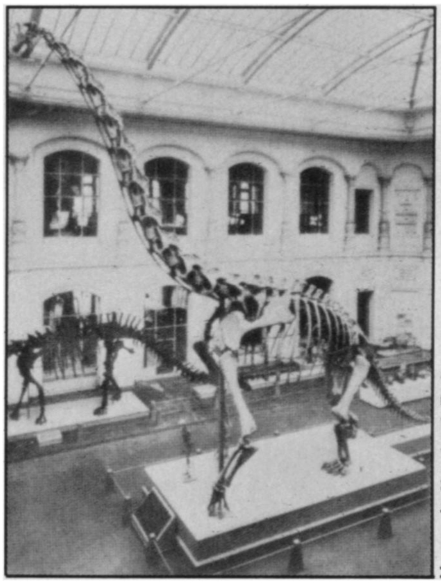
A.J. Charig

All living vertebrate ectotherms (cold-blooded) maintain a sprawling posture. Only endotherms stand fully erect.

researchers have calculated dinosaur blood pressure based on the elevation of head over heart. The blood pressure needed to pump blood up the 18 feet of Brachiosaurus neck is 500 millimeters Hg (human blood pressure is about 120 mm Hg). So at least some dinosaurs had adequate circulation for endothermy. To prevent blood from flowing into the lungs and drowning the animal, blood pressure across the lungs must not be more than about 20 mm Hg. To maintain such a difference in pressure, Ostrom says, those dinosaurs with elevated heads and upright stance must have had fully divided four-chamber hearts. Systemic blood pressures greater than 80 mm Hg and fully divided hearts do not occur in living ectotherms, Ostrom says.

Bone structure has also been cited as anatomical evidence for internal heat production. Dinosaur bone is richly vascularized, like that of mammals and birds. Most living ectotherms have bone with few vascular channels. But Marian Bouvier of Duke University says that correlation is not absolute. Such tissue (called reconstructed Haversian bone) is present in only some endotherms and also in some ectotherms. Thus, bone structure may be related to other factors, such as size, strength and growth rates.

A soft brain structure, detected by its impression on the fossil skulls, provides a suggestion that dinosaur heat was not internally generated. Jan J. Roth of the National Institute of Mental Health reports that many families of lizards have an unfocused parietal, or third, eye associated with the brain's pineal body. Preliminary



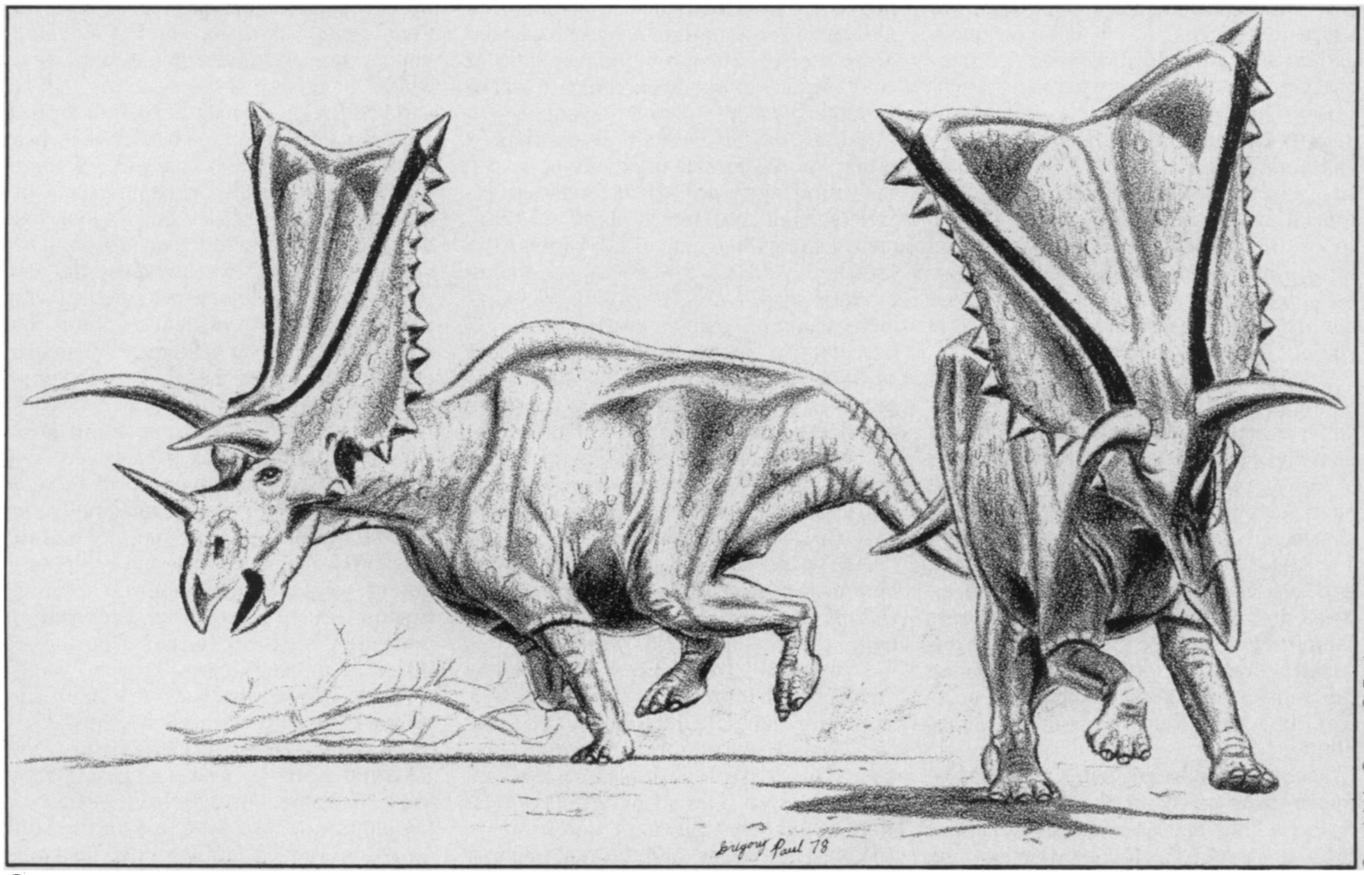
Museum für Naturkunde/Berlin

Brachiosaurus required a powerful pump to get blood to its greatly elevated head.

evidence suggests that the pineal body in birds may play a role in temperature regulation. In lizards, removal of the parietal eye makes the animals raise their temperature excessively by spending more time in warm areas. Roth suggests that the parietal eye is involved in behavioral aspects of temperature control, and would, therefore, be more important in ectothermy than in endothermy.

Roth finds evidence of the modern lizard anatomy, parietal eyes associated with pineal bodies, in fossils of mammal-like reptiles (the ancestors of mammals) and of a few ancestors of dinosaurs. However, most dinosaurs appear to have had neither parietal eye nor pineal body. Roth explains this loss of the entire parietal-pineal complex in terms of environmental change. In contrast to the mammal-like reptiles, late Triassic dinosaurs were becoming adapted to warmer climates. "Precise regulation of body temperature by the parietal-pineal complex would have been superfluous for large reptiles living in a thermally hospitable environment," Roth says. "Some small dinosaurs (certain Coelurosaurs) apparently retained the pineal as have their descendants (birds). These small dinosaurs may have been endothermic," Roth says.

Discovery of dinosaur footprints in Spitsbergen, a Norwegian archipelago in the Arctic Ocean, has been put forth as evidence that dinosaurs were endotherms. Survival in cold climates requires either an internal heater or the ability to burrow. However, Ostrom now says that during the dinosaur era Spitsbergen was



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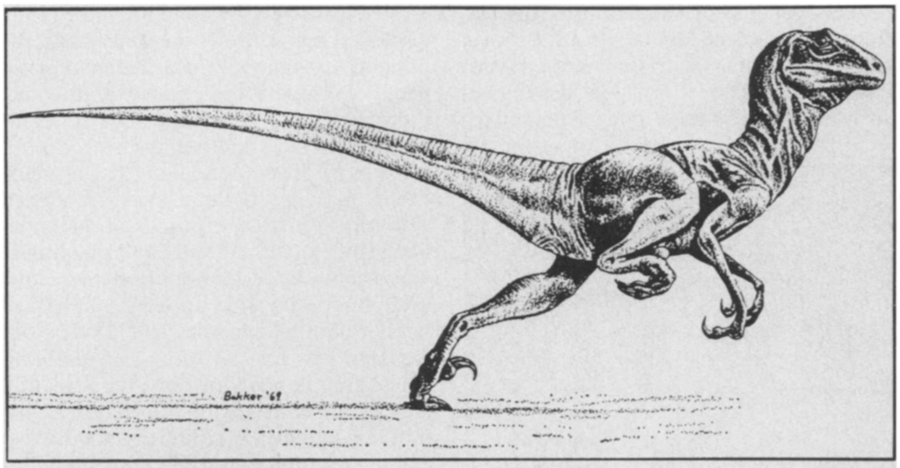
Pentaceratops as fast, long-legged runners. Degree of joint flexion and limb length suggest speeds exceeding those of equal-sized (4,000 kilogram) rhinoceros. The frill, often called armor, was an intimidating display device that also supported enormous jaw muscles powering the bizarre array of teeth this herbivore used for shearing food.



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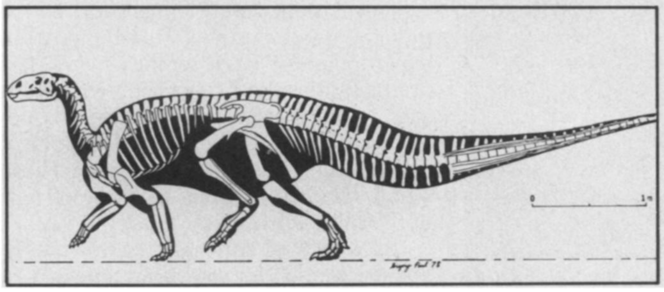

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Lively restorations. Deinonychus *(above), an 8-foot bipedal carnivore, was unearthed in 1964.* Tenontosaurus, *a cow-like herbivore, is shown at a trot.*

much closer to the equator than it is now. Sea-floor spreading has since moved the land masses about on the globe's surface. "In fact, virtually all dinosaur localities appear to have been originally located within 40 to 60 degrees of the equator, corresponding to today's tropical to low temperate zones — the region now inhabited by the vast majority of today's terrestrial ectotherms," Ostrom says.

Dinosaurs' appetites are a major focus of the body temperature debate. Running a continuous internal furnace is expensive, far more costly than the solar energy approach of reptiles. Modern ectotherms (even the Komodo dragon, which can weigh 150 kilograms) consume their own body weight in food every two to four months. Similar-sized endotherms eat that amount in one to four weeks.

Bakker, the most outspoken proponent of dinosaur endothermy, estimates the appetite of extinct animals by comparing the number of predators and of prey in groups of fossils. Links on the food chain can be distinguished by the teeth — "If the teeth are shaped like steak knives, you know it's a predator," Bakker explains. He chooses deposits containing hundreds of specimens that he believes to be an accurate sample of a single community. From reconstruction of skeletons, he can estimate the animals' live body weights and compare the "crop" of predators to the "crop" of prey.

Bakker established criteria for endothermy from calculations on modern animals. He finds that endotherms use about 16 times the fuel of ectotherms of the same size. A prey population that produces 100 tons of dead animals a year can feed a population of mammalian predators that annually produce 2.5 tons of dead predators. (Thus a future archeologist would uncover the skeletons of, for example, 1.5 million mice and 19,000 weasels or 750 antelope and 12 lions.) On the other hand, a population of small lizards also producing a crop of 100 tons can feed a population of larger lizards producing a 40-ton crop. Thus, the predator-prey biomass ratio of ectotherms is about 40 percent and that of endotherms is less than 5 percent.

Bakker has calculated predator-prey ratios for 120 fossil communities. In the early reptile groups he finds predators relatively abundant. The ratio is 40 to 50 percent. Among the mammal-like reptiles the ratio is lower, but not as low as among modern mammals. The fossils of early large mammals gave an average ratio of 5 percent, like today's endotherms. In most of Bakker's 15 samples of dinosaur communities, the ratio also appears the same as in modern mammals. Furthermore, Bakker reports that chronologically the appearance of low predator-prey ratios correlates with the emergence of highly vascularized bone and upright posture. "There is no statistical escape from the conclusion that dinosaurs were endotherms, the same as mammals," Bakker says.

Ostrom criticizes Bakker's approach by suggesting that predator and prey animals may have had quite different habitats, and thus would not be proportionally represented in a fossil deposit. He also says that the ratio, even if an accurate representation, would only apply to predators, not to the prey dinosaurs. And the vast majority of dinosaurs were herbivores.

Bakker argues that large ectotherms could not coexist with large endotherms; the competition would be too rough. Small ectotherms, like lizards, can hide, but dinosaurs would have few hiding places. Today the large turtles and large reptiles all live on islands, isolated from large endotherms. Bakker also says that evolutionarily herbivore dinosaurs are the more advanced; they are descended from the predator dinosaurs. "It would be silly to say they lost endothermy," Bakker insists.

Even among the vegetarian dinosaurs, there is evidence suggestive of a voracious appetite. The two-legged dinosaurs (especially the duck-bills) and the horned dinosaurs were equipped with batteries of grinding and slicing teeth, specialized for processing large quantities of vegetation. Most dinosaurs also had adaptations that would allow breathing to continue during chewing. Ostrom says the voluminous food intake might be a requisite of endothermy and high metabolic rate, or simply a consequence of the dinosaurs' size.

Size itself is a key element in the argument of some who would restrict the dinosaurs to a reptilian realm. Nicholas Hotton of the Smithsonian Institution points out that most dinosaurs were similar in size to rhinoceros or elephants. The largest was probably the *Brachiosaurus*, which weighed more than 60 tons. "Most dinosaurs were larger than all but 2 percent of living mammals," he says.

Hotton takes the absence of small dinosaurs (the smallest was the size of a chicken) as an indication that largeness was crucial. He believes large size was their means of maintaining a constant temperature. Size determines the rate at which an animal loses heat through its surface. Large animals have less surface area per unit volume, so they lose heat more slowly. Reptiles, as well as mammals, exhibit this thermal inertia. One-hundred-kilogram Komodo dragons lose heat no more rapidly than do similarly sized mammals, Hotton says. He also points out that mammals start having trouble getting rid of heat at about that size. Thus, dumping heat, rather than generating it, may have been one of the dinosaurs' problems.

With the sharp disagreement over whether endothermy is irrefutable, likely or unlikely in most dinosaurs, there is plenty of room for further imaginative investigation. Bakker says that much of the research so far has come out of application of "whatever technique you are into." Hotton says, "Everything everyone is presenting is a very loose system. That's how it is in paleontology."

And nature always has a few more surprises. During the discussion following the AAAS symposium, Bakker was asked how he could justify drawings of racing dinosaurs. The objection was that the stress on the joints would be too great for the bone structure as each limb churned back and forth. Bakker had no mathematical answer, but did reply, "White rhinoceros gallop." □