Energetic Giants

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The traditional view of dinosaurs as sluggish behemoths is now being increasingly supplanted by a picture of animals that were in fact vigorous and energetic. This revolution in our understanding is in part due to researchers scrutinizing the remains of these Mesozoic giants... under the microscope

The structure of dinosaur bone tissue is more similar to the bones of birds and mammals than those of typical cold-blooded reptiles. Recent assessments of dinosaur growth rates obtained by analyzing bone cross-sections indicate that tyrannosaurs, for example, matured and reached their largest dimensions in their second decade of life. By contrast, large crocodiles, the present-day reptiles most closely related to dinosaurs, continue to grow over several decades. The largest dinosaurs, the sauropods, grew even more rapidly. Their physiology was therefore more bird-like than typically lizard-like, including in terms of the speed of their metabolism.

Warm blood in tyrannosaur veins?

In March 2005, the world press was captivated by the news that soft tissue (including blood vessels) had been isolated from the thigh bone of a North American tyrannosaur (*Tyrannosaurus rex*). This finding was reported in a groundbreaking article in *Science* by American paleontologists Mary H. Schweitzer, Jennifer L. Wittmeyer and John R. Horner, plus Jan K. Toporski, astrobiologist specializing in biomineralization currently working at Christian-Albrechts University in Kiel. Colorful pictures of the pliable tissues they obtained from bones excavated in Montana definitely added flair to this year's 100th anniversary of the first description of the tyrannosaur, the world's most famous dinosaur species.

Nevertheless, their research was not the first time when 70-million-year-old tyrannosaur bones were successfully shown to contain preserved blood vessels and collagen fibers, bone tissue's organic "reinforcement" element. This had indeed been achieved decades earlier by Prof. Roman Pawlicki, a Polish researcher from the Kraków Medical Academy. He studied Late Cretaceous dinosaur bones that had been retrieved from the Gobi Desert by the Polish-Mongolian Paleontological Expeditions (1963–1971). These included the remains of Asian tyrannosaurs, which were contemporary with the American ones and grew to similarly huge sizes. In articles published from the 1960s through the 1990s (including in *Nature*), Prof. Pawlicki demonstrated that the bones of predatory dinosaurs from the Gobi contained

Karol Sabath

Interest in dinosaurs is not waning: visitors to the stand set up by the Museum of Evolution of the PAN Institute of Paleobiology, at the 2005 Science Picnic in Warsaw are here inspecting a casting of a tarbosaur skull. Was this animal warm-blooded?

Karol Sabath

New findings of soft dinosaur tissue remains are fuelling the ongoing debate about the energy efficiency and speed of these extinct giants

preserved organic substances (lipids, collagen), as well as a dense, three-dimensional network of blood vessels. His work chiefly involved preparing sections for a scanning electron microscope (SEM) by etching the surface of cut and polished bones and taking detailed impressions that revealed the tissue structure. Sometimes, however, he dissolved the entire mineral fraction, leaving just the network of blood vessels behind - as was later done by the team of US researchers. As M. Schweitzer said: "What we did was verify and validate his findings and took them further."

The egg came first

Not long ago it was discovered that female tyrannosaurs prepared for egg-laying in a way akin to female birds – by generating a supplementary layer in their bones prior to the breeding season, allocated for subsequent loss (through the calcium resorption required by eggshell production), thereby protecting the structural part of their bones from decalcification.

In fact, the similarities stretch even further. When American expeditions to the Gobi Desert in the 1920s discovered nests containing elongated dinosaur eggs, yet without any fossilized embryo remains, these eggs were ascribed to the most common herbivorous horned dinosaurs, the *Protoceratops*. One such nest, however, was found to contain the skeleton of a predatory dinosaur with a short, toothless beak. It was thought that this had to have been an intruder killed by the enraged parents, and it was dubbed *Oviraptor philoceratops* (a name meaning "egg thief with a fondness for ceratopian eggs").

In the 1990s, when I completed cataloging and studying the extensive collection of eggs that had been collected by the Polish-Mongolian Paleontological Expeditions, all the elongated eggs from the Gobi were still considered to be protoceratops eggs. Nevertheless, studies using a scanning microscope showed that some of these eggs, called *Elongatoolithus*, had an ultrastructure that was very similar to bird eggs. Encompassing two marked layers, a continuous external one and a "mammillary" internal one, this structure was named "ornithoid" by my Russian colleague, Konstantin Mikhailov. This discovery gave rise to the conjecture that such bird-like eggs had in fact been laid by theropods, the dinosaurs most closely related to birds, rather than by ceratopsians or other herbivorous

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Karol Sabath

dinosaurs, whose evolution had taken a separate path since the Triassic.

This hypothesis received confirmation almost immediately after it was published, when more oviraptor skeletons were found atop clutches of the same type of eggs in Mongolia and China, and oviraptor embryos were discovered inside such shells. Moreover, the position of the adult specimens demonstrated that the parents were brooding over their eggs, and were perhaps protecting them from a sandstorm, stretching out their forelimbs. Sheltering the eggs in this way would have made sense if these limbs were covered in feathers. And indeed, a skeleton of an early oviraptor with quite large feathers on its tail and forelimbs was soon found in China.

Feathery dinosaurs

Nowadays, the mention of feathers makes us think of birds and their ability to fly. Yet feathers initially played a different role: they gave flightless dinosaurs a kind of thermal insulation, reducing heat losses and thereby helping conserve energy.

The notion that dinosaurs, the prehistoric "lizards," might have been covered in plumage verged on heresy until only recently. But nowadays every child who watches popular science programs on television is familiar with the view that birds are in fact flying dinosaurs, and that many non-birdlike dinosaurs were feathered, too. Decisive evidence came when feathered dinosaurs (including the early tyrannosaur *Dilong paradoxus*) and primitive birds were unearthed from Early Cretaceous deposits in the Chinese province of Liaoning.

The first evidence, however, came from somewhere else, and was considerably older. As far back as in the mid-19th century, Prof. Edward Hitchcock in Massachusetts amassed a huge collection of Early Jurassic footprints. In the early 90s, Gerard Gierliński studied Hitchcock's collection at Amherst College. One of the prints, AC-1/7, bears the trace of a sitting dinosaur showing the imprint of its belly. A magnifying glass reveals the existence of brush-like structures along the imprint's edge. Gerliński saw them as the marks left behind by feathers. Hitchkock had presumably been of a similar opinion, but was unsurprised by this, as he considered the three-toed footprints from New England to have been made by large flightless birds.

Nowadays, however, we know that these tracks were left behind by animals living at the outset of the Jurassic, 200 million years ago, long before proto-birds ever appeared.

Based on these discoveries, the world's first natural-sized restoration of a feathered dinosaur was created in Poland. Marta Szubert, the outstanding Warsaw-based paleo-sculptor, produced the feathered dilophosaur dubbed "Dyzio," which was put on display at the Geological Museum of the Polish Geological Institute as part of the 1997 Science Festival. Visitors gazing at this reconstruction find it easy to imagine dinosaurs as nimble, highly energetic animals, more akin to birds than to reptiles.

And meanwhile, under dinosaur's feet...

Yet dinosaurs were not the earth's first high-energy animals. A fast metabolism rate and insulating body coverings were traits that had already appeared previously, in the mammalian line. At first, however, mammals were not so good at cooling their bodies down. And so, throughout the Mesozoic they remained small in size (giving them a more favorable ratio of heat-dispersing surface area to volume) and chiefly led nocturnal lives. When studying dinosaurs, microscopes are usually used to scrutinize bits of bone or shards of eggshell, but the remains of Mesozoic mammals can sometimes be placed under the laboratory lens in their entirety. Prof. Zofia Kielan-Jaworowska, the leader of the Polish expeditions to the Gobi, dedicated most of her scientific career to studying such mammals. This 80-year-old sage of Polish vertebrate paleontology has capped off her career of research with a co-authored book that takes stock of our current knowledge about mammals in the Mesozoic Era - and thus covers two-thirds of the history of our own biological class. This research shows that our early ancestors may actually have been more primitive than the dinosaurs in terms of energy consumption. Nevertheless, the great extinction that came 65 million years ago radically changed the fate of both groups... ■

Wojciech Skarżyński/Institute of Paleobiology PAN

Prof. Zofia Kielan-Jaworowska, leader of the Polish-Mongolian paleolontological expeditions to the Gobi Desert, excavates an oviraptor nest

Karol Sabath

During the age when dinosaurs ruled the Earth, early mammals, supposedly more energetic, did not grow to impressive size – as is shown by this Asioryctes skull fossil

Further reading

http://www.accessexcellence.org/WN/SU/dinovesselstyap05.htm

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