Newly Hatched Dinosaur Babies Hit the Ground Running

Boca Raton, Florida—From 27 July to 1 August, animals with a backbone drew the attention of morphologists, evolutionary biologists, and other researchers.

Therizinosauroid dinosaurs grew up fast. When they chipped their way out of an egg, the animals emerged strong-legged, ready to fend for themselves and find food, according to an analysis of 80-million-year-old fossil dinosaur eggs conducted by a team of paleontologists and developmental biologists.

For the past 6 years, Arthur Cruickshank of the University of Leicester, U.K., Martin Kundrát of Charles University in Prague, Czech Republic, and their colleagues have studied the jumbles of bones and teeth packed into a dozen fossil eggs found in Henan Province, in east-central China. The teeth and bones allowed them to identify the fossils as theizinosauroid, Kundrát reported.

Now, by comparing the dinosaur embryos with embryos of birds and alligators, Kundrát has determined how far along in development each embryo was and has begun to piece together how therizinosauroid young grew to be independent. To do this, Kundrát's team enlisted the help of Terry Manning of Rock Art in Leicester, who spent several years removing the eggshells, etching out the rock inside, and exposing the fossils. The results of Manning's efforts are impressive and provide unprecedented details about dinosaur embryos, says Eric Snively, a paleontologist at the University of Calgary, Canada.

A good egg. This fossil embryo revealed many secrets about one dinosaur's early life.

Manning and Cruickshank first documented the amount of yolk in each egg and the position of each dinosaur embryo. Because the amount of yolk packed around an embryo decreases over time, the degree to which the embryo is squished inside the eggshell is a rough indicator of the embryo's age.

Kundrát got an even better sense of each embryo's developmental age by using the porosity of the fossilized dinosaur skulls, limb bones, and backbones as a guide. A skeleton starts out soft and porous and gradually hardens into bone, so the degree of ossification typically reflects the age of an embryo. Using the known morphology and hardness of alligator bones at different points in embryogenesis, Kundrát was able to sharpen his age estimate for each dinosaur embryo.

Kundrát determined that all the dinosaur embryos were at least two-thirds of the way through their development, and parts of their skeletons were much further along than those of comparably aged alligator embryos. For example, the dinosaur vertebrae were less porous than expected. "They had well-ossified limb bones, so they can walk immediately after hatching," says Kundrát.

As part of their study, Kundrát and his colleagues also gathered the fossilized teeth of the embryos. Those from the youngest embryos resemble the teeth of the other theropods and were well suited for eating meat. In the more mature embryos, although the teeth retained some meat-eating potential, they were more like those seen in adult therizinosauroids, which are presumed to be herbivores. "We could see the transition of the tooth crown and cusp," Kundrát said.

These data suggest that the hatchlings came out of the egg able to chase down prey and consume suitable plants, Kundrát reported. He suggests that these stages of tooth development reflect the evolutionary steps that allowed therizinosauroids to arise from carnivorous ancestors.

"I'm glad to see this [embryo work] done," says Zhe-Xi Luo, a paleontologist at the Carnegie Museum of Natural History in Pittsburgh, Pennsylvania. In addition to their embryos, he notes, the eggs are important in their own right, because they hint at another aspect of the dinosaurs' lives. Until recently, the only adult remains of therizinosauroids in the Far East have been found near Mongolia, about 1,000 kilometers from the site where the eggs were found. This suggests to Luo that these dinosaurs migrated great distances or that they were much more widespread than paleontologists had thought.

Tiny Salamanders Show Their Teeth

For such small animals, salamanders belonging to the *Thorius* genus have posed a big problem: Biodiversity experts can't easily tell different species apart, because many of them look identical. That makes it difficult to count species or understand the animals' evolutionary history. Now, James Hanken of Harvard University has used genetics to classify the animals and place them on a family tree that illuminates the morphological history of the genus. As Hanken reported at the meeting, the tree suggests that a few *Thorius* species have turned back the evolutionary clock, reacquiring traits—including teeth—that their earliest ancestors had lost.

The miniature salamanders, which are native to Mexico, live on moss and inside bromeliads and fallen logs. Hanken, who began studying the animals 30 years ago, has always been fascinated by their size. Although some are much larger, certain *Thorius* species have bodies just 13 mm long, making them the tiniest tailed tetrapods. Packing all the necessary organs into a body that size poses a challenge. "[They] are right up against the edge of vertebrate design," says Hanken. They can't be much smaller, agrees Johan van Leeuwen of Wageningen University in the Netherlands.

Hanken originally thought there were fewer than a dozen *Thorius* species, but by looking for slight genetic differences that readily distinguish one species from another, he and his colleagues quickly identified 14 new species. His group recently added eight more to the list. "Every trip we take, we find one or two new species," says Hanken.

Those results answered one longstanding question: In part because there's little room in those tiny bodies to move parts around, researchers have wondered whether the small size of *Thorius* salamanders would

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Compact package. The tiny *Thorius* is one-tenth the size of many other salamanders.

limit the animals to splitting into just a few species instead of radiating into many. "Hanken's results show that … these salamanders have been radiating just fine," says Jukka Jernvall, an evolutionary biologist at the University of Helsinki, Finland.

That radiation took some surprising turns, however. The skull bones of the tiniest *Thorius* species are mere slivers compared to those of other salamanders, and they no longer interlock to make a solid skull. Their 3-mm-long heads have just enough room for a brain, eyes, nose, and ears—the majority of muscles and connective tissue is missing or greatly reduced. In most species, the upper teeth are even gone.

Yet four of the salamander species have their upper teeth. Hanken had assumed that these species all descended from a common ancestor that had kept those teeth while other branches of the *Thorius* tree lost them. Yet the family tree he and his colleagues constructed revealed that the four species are not closely enough related to have shared such an ancestor. Instead, each species with upper teeth came from toothless stock. These upper teeth "have been reacquired four times," Hanken reported at the meeting.

Three of the upper-toothed species break the miniaturization trend among *Thorius* salamanders. They're larger and have bigger skulls than other extant species. "The presence of teeth seems to be fluid over time and suggests miniaturization and loss of elements might not always be final," says Jernvall.

Some of Hanken's colleagues question his interpretation, noting that the common wisdom holds that once a trait disappears from a group of organisms, it rarely resurfaces. Hanken's conclusion is "something that's hard to defend," says Ann Huysseune of Ghent University in Belgium. But Hanken argues that these small vertebrates must have had a lot of evolutionary tricks up their sleeves in order to survive tough times. He points to the success that small animals in general have had after mass extinctions and attributes that to their ability to rapidly change and adapt.

Thorius species, he thinks, may have retained the capability of making upper teeth, even if their tooth-building program became short-circuited. The reappearance of upper teeth in the four salamander species, says Hanken, "offers an example of latent developmental potentialities that reside within living species but which may not be manifest or expressed until far into the future."

Snake Tartare—Quite a Bodyful

Feasting on everything from ant larvae to mammals seemingly too big to swallow, snakes have eclectic tastes. Some even like to eat other snakes. Such slithering snacks present particular challenges if the snake being consumed is longer than the snake doing the eating. "It's a little like me swallowing you," says Margaret Rubega, a functional morphologist at the University of Connecticut, Storrs.

At the meeting, Kate Jackson, a herpetologist now at the University of Toronto, Canada, described how x-ray scans and old-fashioned dissection revealed that a surprisingly stretchy stomach holds the key to successful snake consumption. The study, says Rubega, is "a wonderful, creative use of a variety of tools."

While at Harvard University, Jackson bought juvenile king snakes, reputed snake eaters, and corn snakes from a pet store. When she and her colleagues put the two species into a cage, the snakes would immediately turn into a writhing ball of whipping heads and tails. After just a few minutes, however, the king snake would typically sink its teeth into the corn snake. The king snake, which is not venomous, would then spend the next 8 hours squeezing its prey to death.

Once it had subdued its meal, the king snake would start with the head of the corn snake.* Swallowing required two motions, Jackson reported. As is typical for some snakes, the left and right sides of the jaw can move independently, and each side alternated between grabbing the prey and pulling it back—a "jaw walk," says Jackson's colleague Elizabeth Brainerd, a functional morphologist at the University of Massachusetts, Amherst.

The king snake eventually switched to a different swallowing technique. It would grab hold of its prey, then kink up its vertebrae, and finally, let go and straighten out. "It slides the body over the prey," says Jackson. Within 2 hours, a corn snake would disappear down a king snake's gullet.

Jackson expected ingestion to come to an abrupt halt once the king snake had swallowed the equivalent of two-thirds of its length; that's the end of its stomach. But the king snake managed to cram in the whole corn snake. A dissection of the newly satiated snake revealed how it achieved this gluttonous feat: "The stomach was stretched to 91% of its body cavity," Jackson reported. All the other organs were squished out of the way. "I am amazed at the way they do it," comments David Wake, a herpetologist at the University of California, Berkeley.

The stomach's stretchiness could only partly explain how the king snake swallowed prey bigger than itself. Telltale bulges down the length of the king snake suggested another trick. When Jackson and her colleagues x-rayed a king snake with its ingested prey, they discovered that the corn snake was, in the words of Brainerd, "compressed like an accordion."

Jackson found that even after a king snake had finished taking a corn snake down its throat, it sometimes spit the whole snake back up, particularly if startled. "That's a big risk," says Wake, because it takes so much energy to procure such a meal in the first place. On the other hand, a yen for snakes has its advantages.

Yum, yum. Snakes use special tricks to eat other snakes. Trace the two tails to see who is eating whom.

For its size, the king snake gets the richest meals of all the nonvenomous snakes. "The king snakes are able to get the energy input of a very large meal without having the large mouth-gape specializations and venom of vipers," says Brainerd. Thus, Jackson proposes, even if a dinner is sometimes wasted, it's worth the effort.

–ELIZABETH PENNISI

* Video: www.bio.umass.edu/biology/brainerd/video-library.php

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