Agonized pose tells of dinosaur death throes

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The earliest feathered dinosaur, Archaeopteryx (plumage not shown). Drawn from specimen at Humboldt Museum, Berlin. The skull is about six inches long. Credit: UC Berkeley

The peculiar pose of many fossilized dinosaurs, with wide-open mouth, head thrown back and recurved tail, likely resulted from the agonized death throes typical of brain damage and asphyxiation, according to two paleontologists.

A classic example of the posture, which has puzzled paleontologists for ages, is the 150 million-year-old Archaeopteryx, the first-known example of a feathered dinosaur and the proposed link between

dinosaurs and present-day birds.

"Virtually all articulated specimens of Archaeopteryx are in this posture, exhibiting a classic pose of head thrown back, jaws open, back and tail reflexed backward and limbs contracted," said Kevin Padian, professor of integrative biology and curator in the Museum of Paleontology at the University of California, Berkeley. He and Cynthia Marshall Faux of the Museum of the Rockies published their findings in the March issue of the quarterly journal Paleobiology, which appeared this week.

Dinosaurs and their relatives, ranging from the flying pterosaurs to Tyrannosaurus rex, as well as many early mammals, have been found exhibiting this posture. The explanation usually given by paleontologists is that the dinosaurs died in water and the currents drifted the bones into that position, or that rigor mortis or drying muscles, tendons and ligaments contorted the limbs.

"I'm reading this in the literature and thinking, "This doesn't make any sense to me as a veterinarian,'" said lead author Faux (pronounced fox), a veterinarian-turned-paleontologist who also is a curatorial affiliate with Yale University's Peabody Museum. "Paleontologists aren't around sick and dying animals the way a veterinarian is, where you see this posture all the time in disease processes, in strychnine cases, in animals hit by a car or in some sort of extremis."

Faux and Padian argue in Paleobiology that the dinosaurs died in this posture as a result of damage to the central nervous system. In fact, the posture is well known to neurologists as opisthotonus and is due to damage to the brain's cerebellum. In humans and animals, cerebellar damage can result from suffocation, meningitis, tetanus or poisoning, and typically accompanies a long, slow death.

Some animals found in this posture may have suffocated in an ash fall

during a volcanic eruption, consistent with the fact that many fossils are found in ash deposits, Faux and Padian said. But many other possibilities exist, including disease, brain trauma, severe bleeding, thiamine deficiency or poisoning.

"This puts a whole new light on the mode of death of these animals, and interpretation of the places they died in," Padian said. "This explanation gives us clues to interpreting a great many fossil horizons we didn't understand before and tells us something dinosaurs experienced while dying, not after dying."

Also, because the posture has been seen only in dinosaurs, pterosaurs and mammals, which are known or suspected to have had high metabolic rates, it appears to be a good indicator that the animal was warm blooded. Animals with lower metabolic rates, such as crocodiles and lizards, use less oxygen and so might have been less traumatically affected by hypoxia during death throes, Padian said.

Padian acknowledged that many dinosaur fossils show signs that the animal died in water and the current tugged the body into an arched position, but currents cannot explain all the characteristics of an opisthotonic pose. By studying a large number of fully articulated fossil skeletons, he and Faux were able to distinguish animals that underwent post-mortem water transport, a non-biological or abiotic process, from those with the classic "dead-bird" posture, which they interpret to be the result of biological processes.

Faux, who also works as a disaster veterinarian from her home in Lewiston, Idaho, set out to test other post-mortem processes - rigor mortis, which is the temporary stiffening of muscles after death; and the drying of muscles, tendons and ligaments - that some paleontologists credit with creating the opisthotonic posture.

Working with a raptor recovery center, she obtained birds that were so badly injured they had to be euthanized - great horned owls, red-tailed hawks and falcons - and observed them during rigor mortis, checking periodically for eight to 10 hours to see if they moved during the process.

"In horses and smaller animals, rigor mortis sets in within a couple of hours, so I just looked to see if they were moving or not," Faux said. "And they weren't moving. They were staying in whatever position I'd left them in. I thought, 'If birds aren't doing it, and I'd never observed a horse doing it, then why would dinosaurs be doing it?'"

The idea that drying causes muscles or tendons to contract asymmetrically also didn't make sense, she said, based on her veterinary experience and an experiment she conducted with two euthanized red-tailed hawks, which she dried for two months in Styrofoam peanuts. Most joints have counterbalancing muscles that dry the same way, she said, so there was no reason to expect that the muscles would turn a joint during drying. She found no post-mortem movement. She also pinned beef tendons as they dried, and though they shrank a bit, they did not shrink enough even to dislodge the pins. Given these observations, it is hard to imagine how shrinking tendons or muscles could drag a heavy creature into a different position, the researchers noted.

Padian pointed out, too, that all opisthotonic dinosaurs are very well preserved, meaning they evidently did not sit out in the open for long, or scavengers would have quickly scattered the bones. So, he wondered, how could they have been exposed long enough to dry out?

The only explanation that makes sense, they concluded, is central nervous system damage. The cerebellum is responsible for fine muscle movement, controlling, for example, the body's antigravity muscles that keep the head upright. Once the cerebellum ceases to modulate the

behavior of the antigravity muscles, Faux said, the muscles pull at full force, tipping the head and tail back, contracting the limbs and opening the mouth.

Padian and Faux urge reanalysis of many fossil finds, referring, for example, to a mass death uncovered in Nebraska in the early 20th century. They argue that cerebellar dysfunction explains the opisthotonic posture of the numerous camel-like fossils better than does the common explanation - that the animals died in a stream and were washed into an eddy or backwater.

The authors also point to a fossil of Allosaurus, a T rex-like animal, that displayed bone lesions suggestive of a bacterial infection that also can lead to meningitis, a disease that can produce opithotonus. The authors point out that their explanation of the opisthotonic posture in dinosaurs and other animals provides a way to assess the role played by microbes in evolution, whether through disease or through other processes such as algal blooms - so-called "red tides" - that can suffocate aquatic animals.

This example and others "suggest that reevaluation may be in order for an untold number of paleoenvironments whose story has been at least partly explained on the basis of the death positions of many of their fossil vertebrates," the authors write in their Paleobiology paper.

Source: UC Berkeley

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