Origins and Extinctions: Paleontology in Chicago

After waiting 4 years to get together at the Fifth North American Paleontological Convention, 500 paleontologists finally got their fill at Chicago's Field Museum of Natural History late last month: more than 300 presentations that ran the usual gamut from the origin of species to their disappearance. Everyone's favorite extinct beasts, the dinosaurs, looked cuddlier than ever with new evidence that some were warm-blooded. Asteroid and comet impacts were proposed as a pervasive agent of extinction. And the case for the tropics as a breeding ground of diversity grew stronger.

Are the Tropics a Cradle of Diversity or Only a Museum?

A thousand species of clams grace the waters of the Philippines today, but fewer than 100 can be found off the north coast of Alaska. Look at birds, plants, ants, snakes, and the pattern is the same: Compared with higher latitudes, the tropics are enriched with a wider variety of plant and animal species, and it's been that way for millions of years.

Explaining the disparity has proved much harder than measuring it. Does evolution spin out new species at a faster clip in the tropics? Or are they just a nice, safe place where species that mostly arose elsewhere can find some shelter from the ravages of extinction—a museum, in other words? At the meeting, paleontologist David Jablonski of the University of Chicago came down firmly on the side of the tropical oceans, at least, as a cradle of diversity—not just a repository. An explanation, he thinks, may well lie in the newly appreciated instability of the tropical environment.

The many gaps in the fossil record make it tricky to pin down just where new creatures arose, so Jablonski tried to get around the problem by narrowing his search to the record's best part. He confined himself to marine invertebrates—clams, snails, barnacles, and the like—because they are better preserved than are fish and land animals, and he looked only at the last 250 million years. Because narrow groupings are harder to trace, Jablonski moved up the taxonomic scale to orders. And he stuck with orders whose members hold up best during fossilization and thus produce abundant fossils.

To assemble his sample, Jablonski drew on the literature, museum collections, and consultations with other experts. When he adjusted the resulting record for continental drift, it showed what looked like a dead heat between the tropics and higher latitudes in the race to generate new orders, such as crinoid sea-lilies that lacked stalks (for added mobility) or sea urchins streamlined for easier burrowing.

But Jablonski suspected that was not the last word. Even in the most carefully assembled fossil record, any comparison between the tropics and temperate latitudes might be skewed by paleontologists' predilection for doing their fossil-hunting close to home—that is, in mid-latitudes. The uneven search effort might mean that some orders actually born in the tropics will appear to have originated at higher latitudes. But Jablonski had a way to measure the effect: The poorly preserved orders he had excluded from his sample should be sensitive indicators of any bias because their fossils are scarce. And Jablonski found that even though these orders should have originated in the tropics just as often as the well-preserved orders, they showed a dramatic skewing toward temperate latitudes. Taking that bias into account, Jablonski concluded that his sample actually reflects a significant preference for tropical origins.

At least in the case of marine invertebrates, that finding settles a controversy dating back more than 50 years, but it leaves paleontologists in the dark about the cause. In the 1960s and 1970s, researchers who guessed that tropical diversity was homegrown argued that the stability of the tropics allowed plenty of time for evolution to create new species. But it turns out that the tropics have not had the luxury of long-term stability; change has been frequent there too, says Jablonski, as evidenced by the localized extinction of corals, among other signs.

Now it seems that change itself might be key to the tropics' role as the cradle of diversity. Jablonski and David Bottjer of the University of Southern California have recently shown that orders originate far less often in deep, offshore waters, where environmental changes are subdued, than in shallow, near-shore waters, where changes in sea level, storms, and climate change cause frequent and dramatic habitat shifts. The reason, Jablonski speculates, is that highly disturbed shallow environments might tend to breed a fauna resistant to extinction. The more resistant to extinction a region's fauna is, one theory goes, the more likely it is that any novel forms would survive to found new orders.

And shallow marine environments abound in the tropics, Jablonski notes, in the form of coral reefs, which extend the disturbed environment from the near-shore region outward across the continental shelf. Reef environments, he speculates, might give the tropical cradle the rocking it needs.

How Large a Role for Impacts In Pulses of Extinction?

There was nothing shy about the meeting's opening plenary lecturer. To an audience generally skeptical of things extraterrestrial, paleontologist David Raup of the University of Chicago proposed an "extreme—and seemingly ridiculous—hypothesis": that comet and asteroid impacts are responsible for almost every burst of extinction of the past 600 million years, from the five mass extinctions down to the blips of extinction that recur every million years on average. The notion was a bit hard for some of the audience to swallow—especially since paleontologists as a group have been slow to accept an impact as the cause of even the mass extinction 65 million years ago.

Even Raup calls his hypothesis "somewhat rash," and he wouldn't swear that it's the whole truth. Instead, he's trying to stake out one extreme in the debate over the causes of extinction, a debate that is heating up as the case for an impact-extinction link 65 million years ago is strengthened and others are proposed.

As drivers of widespread extinction, says Raup, large-body impacts fit the bill nicely. Impacts wreak their effects quickly enough to prevent species from avoiding extinction by adapting or retreating to temporary refuges. Those effects are felt around the world and in different habitats. For example, sun-blocking dust clouds encircle the globe, ravaging land-dwelling species with months of cold, and nitric acid forged by the impactor's passage through the atmosphere acidifies the upper ocean.

Raup also argues that impacts deserve more attention since other proposed extinction drivers—sea level fall, climatic cooling, and volcanic eruptions—have come up short. His favorite example is the failure of repeated ice ages during the past couple of million years to produce more than minor extinctions.

All that encouraged Raup to make a stab at testing his impact idea, based on the premise that if extinction events and impacts are causally linked, they should be roughly correlated in size and frequency. So far, Raup reports, this statistical test suggests the hypothesis is "not as ridiculous as it first seemed." At one end of the spectrum, impacts generating craters 140 kilometers in diameter, among the largest known on Earth, strike about every 100 million years on average. That's about the same frequency as the largest extinction events.

At the other end of the spectrum, impacts

Cold- versus warm-blooded? Comparing the oxygen isotopes in the bone of a cold-blooded Komodo dragon, up to 3 meters long, and in dinosaur fossils suggests some dinosaurs were warm-blooded.

producing craters 25 kilometers in diameter—a reasonable size for the smallest events likely to cause an extinction pulse, according to Raup—strike about once every million years. Perhaps not coincidentally, the smallest extinction pulses punctuate the fossil record at intervals of about a million years.

Such consistency arguments have not swayed other paleontologists. Steven Stanley of Johns Hopkins University, a defender of the climate change mechanism, goes further than most of his colleagues when he says, "I certainly believe there's a very strong case for the terminal Cretaceous event [when the dinosaurs disappeared 65 million years ago] being caused by an impact. A lot of these events may have been caused by extraterrestrial impacts. But are all pulses of extinction impacts? I would be very skeptical."

Stanley points to specific extinction events that seem closely tied to climatic cooling, especially one about 34 million years ago when the first major ice sheet formed on Antarctica. True, the further cooling of the Pleistocene didn't bring another burst of extinction, says Stanley, but by the time those glaciations came along most of the species susceptible to extinction had probably been weeded out by the long-term cooling.

Stanley concludes that Raup's hypothesis "is not going to be the whole answer." Just how much of an answer it is should become clear, says Raup, as investigators get more and better dates for impacts. In addition to the terminal Cretaceous event, impacts have been tentatively linked to major extinctions about 367 and 202 million years ago. If Raup is anywhere near right, the links should continue to mount.

Isotopic Thermometer Hints at Warm-Blooded Dinosaurs

Recent fossil finds that suggest some dinosaurs migrated hundreds of kilometers and thrived in the chill of the high latitudes have challenged the traditional view of dinosaurs as cold-blooded and sluggish—something like huge crocodiles. But in the absence of direct evidence of dinosaur warm-bloodedness, many researchers have been reluctant to abandon their long-held image of the beasts. Now, however, thanks to some new results presented at the meeting, "it's looking good for warm-blooded dinosaurs," says William Showers of North Carolina State University.

In the past, the warm-blooded—cold-blooded dinosaur debate had hinged on circumstantial evidence suggesting a high metabolic rate, such as skeletons that seem designed for sustained, high-speed running. Showers, an oceanographer, and paleontologist Reese Barrick of the University of Southern California think they have something better: a way to take the temperature of long-dead creatures by measuring oxygen isotopes in their bones. Though skeptics worry about possible spurious signals, the two researchers think they have what Barrick calls the first "direct, quantitative evidence" about body temperature in dinosaurs.

That evidence comes from a twist on an old technique. When living things combine oxygen with phosphorous or carbon to form bones or shells, the ratio of its two isotopes—oxygen-16 and oxygen-18—depends on the temperature. The technique has been applied for decades to the carbonate shells of marine microfossils to take the temperature of ancient oceans. Yehoshua Kolodny of the Hebrew University in Jerusalem later tried it on the phosphate of fossil fish bones to learn the temperature of ancient fish and their environments.

Instead of trying to measure absolute body temperatures, Barrick and Showers looked for the hallmark of warm-bloodedness: temperature stability. A cold-blooded animal's body temperature varies as its environment warms and cools, so that the isotopic signal recorded in different parts of a bone should fluctuate depending on when the bone was deposited. What's more, the extremities of a cold-blooded animal should be substantially colder than its core.

Barrick and Showers tested their technique by analyzing the bones of a Komodo dragon—a giant lizard—that had died at the San Diego Zoo. The isotopes showed that while this cold-blooded animal was alive, its tail bones were 2° to 9°C cooler than its ribs or vertebrae. In contrast, isotopes from the bones of a cow raised in a stockyard recorded the same average temperature whether the bone was from the core or extremities.

That encouraged Barrick and Showers to try the technique on dinosaur bones. Their criterion for warm-bloodedness, based on living animals, was a disparity of 4°C or less between core and extremities. Two juvenile dinosaurs, a small herbivore called *Orodromeus* and a Ceratopsian, showed a difference of 3° and 4°C, respectively—within the bounds of warm-bloodedness. They also exhibited a relatively small range of temperature for different samples of the same bone, as would be expected for a warm-blooded animal.

The picture blurred a little when Barrick and Showers analyzed bones from an adult *Camarasaurus*, one of the massive, vegetarian sauropod dinosaurs. It had no temperature disparity at all from core to extremities, but some of the bones showed more isotopic variability than would be expected of a warm-blooded animal. But maybe it wasn't warm-blooded all its life, Barrick ventures. It might have undergone the kind of metabolic shift paleontologist John Horner of Montana State University has suggested for other dinosaurs. Warm-blooded as a juvenile, the sauropod might have lost most of its temperature control as it aged and its metabolism slowed.

Then again, all these isotopic signals might say more about the bones' decay than their temperatures during life. Kolodny himself sprinkled that bit of cold water on the evidence for warm-blooded dinosaurs when, after the talks by Showers and Barrick, he discarded his own planned talk and launched into a cautionary tale. He now sees isotopic and geochemical signs that the calcium phosphate of fossils may not be the calcium phosphate of the bone of the living animal; ground water may have dissolved the original mineral and replaced it with different phosphates. "I would be glad to be proven wrong," he said. "I've made a good part of my living with this. But we must find some criterion to justify this technique."

Barrick and Showers think they have such a criterion in infrared spectroscopy, which provides some measure of the extent of alteration by tracking crystal size. Just as Kolodny fears, it shows that some fossils have been altered, Showers noted, but it also suggests that others should be reliable. And the pair has something else in the works: an analysis of bones from a fossil crocodile, assumed to be cold-blooded, that was preserved in the same rocks as dinosaur bones. If the crocodile's isotopes say "cold-blooded," the heat will really be on the dinosaur traditionalists.

–Richard A. Kerr