PALEONTOLOGY

Will Fossil From Down Under Upend Mammal Evolution?

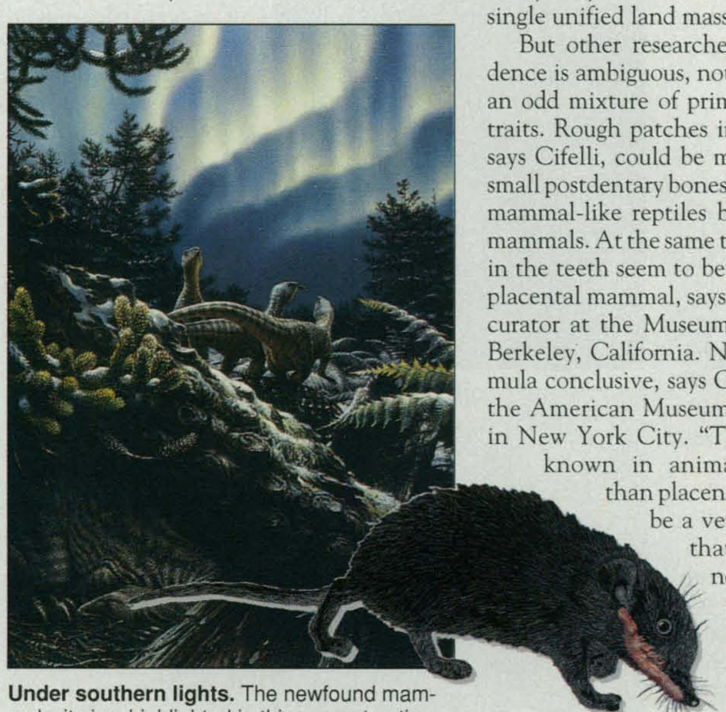
Eight months ago, Nicola Barton cracked open a rock on a beach in southern Australia and found a tiny tooth. Still embedded in the rock was the rest of the fossil: a total of four teeth in a 2-centimeter jaw. The tooth fairy could not have been kinder. The fossil fragment Barton discovered could cause researchers to rethink some long-held views about the early history of mammalian evolution. Says Richard Cifelli, curator of vertebrate paleontology at the Oklahoma Museum of Natural History in Norman: "It will have the scientific world at the edge of its seat."

Paleontologist Thomas Rich of the Museum of Victoria in Melbourne, who oversees the dig where Barton was working as a volunteer, has spent 26 years looking for the extinct ancestors of Australia's fantastic mammalian fauna with his wife-colleague Patricia Vickers-Rich of Monash University in Clayton, Australia. Until the discovery of the 115-million-year-old jaw, practically all they had ever found were dinosaurs. "The hardest fossil to find is the first one," says Rich. The fossil, which the Riches and their colleagues describe in this issue of *Science* (p. 1438), is a first in many ways. Called *Ausktribosphenos nyktos*, it is the oldest mammal fossil yet found in Australia. And if Rich's suspicions are correct, it is a most un-Australian mammal. Instead of being an ancestor to the continent's pouched marsupials or egg-laying monotremes, he believes it may be a placental mammal—one that nourishes its developing embryo within the mother's uterus.

That would put placental mammals down under 110 million years earlier than believed, and it would upend paleontologists' ideas about mammal evolution. "All hell would break loose," says paleontologist David Archibald of San Diego State University. "Both the time and the place of origin of placentals would be off." But even if the jaw's shrew-sized owner isn't a placental, it could still rearrange mammals' family tree by altering the timing of its branching points or adding a new limb. "It's extremely important, whatever it is," says Cifelli.

The family tree of mammals is rooted more than 200 million years ago. Most paleontologists believe that monotremes arose early and that the higher mammals—placentals and marsupials—diverged from a common ancestor in the Early Cretaceous period, between 144 million and 98 million years ago. At that time, the continents were grouped into two large land masses, Laurasia in the north and Gondwana in the south. Based on the smattering of known Cretaceous fossils, paleontologists believe that placental mammals originated in Asia, then migrated to North America.

Placentals and marsupials remained confined to the Northern Hemisphere until about 65 million years ago, when an island chain may have allowed both kinds of mammals to enter South America. Marsupials alone, however, continued south across Gondwana and into Australia. Bats followed, but terrestrial placentals are not thought to have entered Australia until about 5 million years ago, long after that continent had broken free of Gondwana. By then it had drifted close enough to Southeast Asia for island-hopping rodents to finally reach it.



Under southern lights. The newfound mammal—its jaw highlighted in this reconstruction—co-existed with dinosaurs at a time when Australia lay close to the South Pole.

P. TRUSLER/MONASH EARTH SCIENCES INSET: T. H. RICH, ET AL.

Rich thinks the teeth and jaw of *A. nyktos* may tell a dramatically different story. Like other placentals and marsupials, the fossil has tribosphenic molars, specialized for both cutting and crushing food. But because the jaw lacks other features seen in the lower jaw of marsupials, Rich puts it in the placental camp. He has also inferred the shape of the upper molars from the wear patterns of the teeth and deduced the creature's "dental formula," the number of each type of tooth. Both the upper molars and the dental formula—five premolars and three molars—may link *A. nyktos* with placental mammals, Rich says.

If a placental mammal was in Australia more than 100 million years ahead of schedule, says Cifelli, "all bets are off" as to where placentals originated: "If they were in Australia then, there's no reason they couldn't have also been in South America, Antarctica, and perhaps Africa. You could make an argument for any place of origin." Rich agrees, noting that shrew-size fossils like *A. nyktos* might be waiting to be discovered elsewhere. "You're not looking at elephants. We could have easily missed them; they could be on every darn continent." He and others add that the presence of early placental mammals in both Asia and Australia—far apart in the Early Cretaceous—could push back the time of origin for higher mammals. They might have diverged from their primitive forebears before the breakup of Pangaea some 180 million years ago, when it would have been relatively easy for them to disperse across the single unified land mass.

But other researchers say that the evidence is ambiguous, noting that the jaw has an odd mixture of primitive and advanced traits. Rough patches inside the lower jaw, says Cifelli, could be marks left by a set of small postdentary bones, common in ancient mammal-like reptiles but absent in higher mammals. At the same time, certain patterns in the teeth seem to belong to an advanced placental mammal, says William Clemens, a curator at the Museum of Paleontology in Berkeley, California. Nor is the dental formula conclusive, says Guillermo Rougier of the American Museum of Natural History in New York City. "That [5/3] formula is known in animals more primitive than placentals," he says. "It may be a very primitive formula that neither precludes nor supports *A. nyktos* as a placental."

Clemens believes that the fossil is not a placental at all, but a remarkable new animal that should spark new thinking about mammal evolution on the southern continents: "We've been thinking in terms of the old Sherwin-Williams paint ads—a globe and a can of paint being poured on the North Pole and dripping down." Convergent evolution could explain why this southern creature has dental features that resemble those of placentals, Clemens adds. Paleontologist Rosendo Pascual at the La Plata Museum in Argentina agrees: "This mammal is something totally different." Along with other recent Cretaceous finds on southern continents, it indicates that mammals had an extensive evolutionary history in Gondwana at that time, he says.

Cifelli sees a third possibility: that *A. nyktos* may be an advanced member of the peramurans, an early group of mammals believed to have spawned placentals and marsupials. To him, the slender jawbone and molar structure also look reminiscent of monotremes, considered among the oldest and most primitive of all mammals. "This new thing appears to be intermediate between peramurans and monotremes, suggesting that monotremes share a much more recent ancestor with higher mammals than previously thought," he says. If so, monotremes would jump up the family tree by about 50 million years, making these odd egg-laying mammals closer cousins to placentals and marsupials.

Other paleontologists think the fossil is too fragmentary to start redrafting the family tree. Instead, says Rougier, it should spur paleontologists to sharpen all their thinking about the early evolution of mammals: "The discovery will force us to take another look at the evidence for an early origin of placentals and to evaluate what features diagnose the major groups of mammals."

As for Rich, he welcomes the discussion. "Science is a democracy," he says. He hopes to advance the debate by finding more bones. A complete skull would help, as would other parts of the skeleton. "Now we know there is one hole in all of Australia where this kind of fossil occurs," Rich says. "This is where Pat and I can spend the rest of our lives, God willing."

–Bernice Wuethrich

Bernice Wuethrich is an exhibit writer at the Smithsonian's National Museum of Natural History in Washington, D.C.

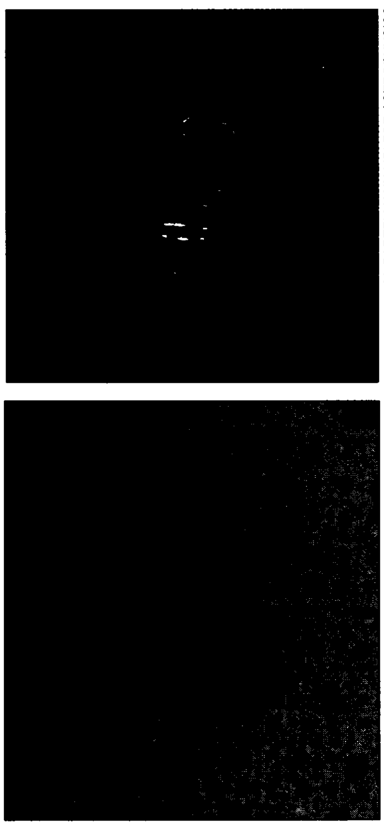
COSMOLOGY

Clusters Point to Never-Ending Universe

Until recently, the outlook for the expanding universe has varied with cosmological fashion. At times, the consensus view held that the universe contains enough mass for gravity to slow its expansion to a stop; at other times, cosmologists have doomed it to expanding forever. Lately, however, evidence ranging from galaxy clusters to distant supernovae has favored an ever-expanding, "open" universe. Now add another vote for an open universe, from the number of images from light-bending "gravitational lenses" in the sky.

A team of German and British researchers has simulated how the vast clusters of galaxies that bend the light of objects behind them should evolve over time in universes containing different densities of matter. They then compared the results to the number of gravitational lens images actually seen in the sky. The verdict: The simulation that best matches the observed lensing images is one that assumes a low-density, open universe. "[This] work may be the strongest single piece of evidence [for an open universe] if it holds up," says Neil Turok of Cambridge University.

According to the general theory of relativity, light from a distant galaxy that passes close to a massive galaxy cluster on its way to Earth will be bent, with the cluster acting like a lens and producing an arc-shaped image of the distant galaxy. "In order for this process to be effective, you need the cluster—that is the gravitational lens—at roughly half the distance from us to the sources," says Matthias Bartelmann of the Max Planck Institute for Astrophysics near Munich, Germany, head of the modeling team. The clusters develop through the entire lifetime of the universe, at a rate that depends on the overall density of matter in the universe. So the number of dense clusters that have ended up in the right place at the right time to act as lenses is a powerful probe of the universe's overall mass density. "The lensing effect is very nonlinear—it reacts very strongly to changes in cluster evolution or in the compactness of the clusters," says Bartelmann.



M. BARTELMANN/MPI FOR ASTROPHYSICS

JEAN-PAUL KNEIB/UNIVERSITY OF TOULOUSE

Long lenses. Comparing simulated *(top)* and observed arcs puts focus on an open universe.

In work that will be published in *Astronomy and Astrophysics*, he and Munich colleagues Andreas Huss and Jörg Colberg, along with Adrian Jenkins and Frazer Pearce of the University of Durham in the United Kingdom, began with two computer models that simulate the evolution of galaxy clusters. As input, the models required an estimate of the distribution of matter in the primordial universe, along with the universe's mean mass density and a parameter known as the cosmological constant—a hypothetical energy embedded in empty space, which may also influence the overall expansion of the universe. The researchers allowed the models to evolve until they reached the current age of the universe. The group then computed the lensing ability of the clusters that had emerged in each model and the number of arcs that would be seen from Earth.

Both simulations showed that a universe with just one-third of the mass density needed to stop its expansion—along with a small or zero value for the cosmological constant—would have dense clusters in the right numbers and places to produce about 2500 arcs across the sky. That number is a good match to the observed number of arcs, which is somewhere between 2300 and 2700. When the researchers wound up the cosmological constant, "the number of arcs goes down to about 250," says Bartelmann, "and when I then turn up the matter density … the number of arcs reduces by another factor of 10 to about 25 on the whole sky." The dramatic differences in the outcome show, says Harvard University's Ramesh Narayan, that "this is quite a sensitive method to distinguish among models."

Narayan cautions that simulating cluster formation is "delicate." Bartelmann adds that the density distribution of the primordial universe is the largest uncertainty in the modeling, one that won't be dispelled until the cosmic microwave background—which records primordial density fluctuations—is mapped in detail by NASA's forthcoming Microwave Anisotropy Probe mission and the planned European Planck satellite.

Princeton University's Neta Bahcall notes, however, that Bartelmann's results on cosmic mass density are in "excellent agreement" with her own, based on direct counting of galaxy clusters. The findings are also in accord with direct measurements of how cosmic expansion has changed over time (*Science*, 31 October, p. 799). This forecast for the fate of the universe may be more than current fashion.

–Andrew Watson

Andrew Watson is a writer in Norwich, U.K.