environments, for example in areas where sand flats are patchy and mobile larvae might be swept into deep water.

Meanwhile, everyone is interested in whether *Manx* played a role much earlier in evolution, 550 million years ago when the chordates first evolved. Many biologists think developmental genes may have been involved in this event, for mutations in such genes offer a plausible way to dramatically alter an organism's body plan, and certainly *Manx* is now a leading candidate. Raff and Carroll expect researchers to start scrambling to find *Manx* equivalents in model species such as mice and frogs, to see whether the gene governs notochord and tail development in these true vertebrates.

If so, then it's possible that one of the classical divides in animal life could be traced back to a single genetic change. Of course, "what we don't know, and what [our] studies cannot tell us, is what the true genetic event was," says Nipam H. Patel, developmental biologist at the University of Chicago. "You can't run the tape of time backward, so all you can do is make good guesses."

–Elizabeth Pennisi

PALEONTOLOGY

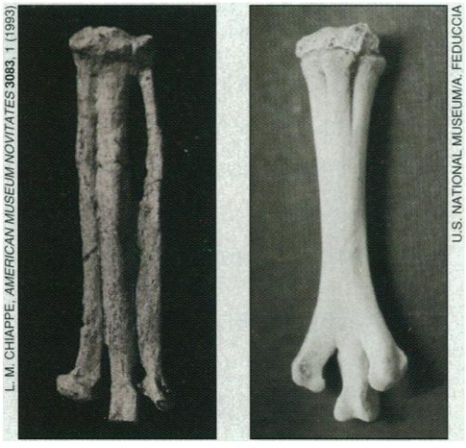
Early Birds Rise From China Fossil Beds

Paleontologists have been arguing about the ancestry of modern birds ever since 1861, with the discovery of the first indisputable bird, *Archaeopteryx*, in Bavaria. With conspicuous teeth, a lizardlike tail, and feathers draped over a dinosaurlike body, this 150-million-year-old fossil has been touted as a "missing link" between birds and dinosaurs. But the bones of modern birds look different, and researchers have been unable to agree on whether *Archaeopteryx* or its close cousins did indeed lead to modern birds; some ornithologists even doubt that modern birds descended from dinosaurs. On page 1164, Chinese and American scientists present new fossils sure to take the debate to new heights.

The bones represent what may be the oldest modern-looking bird, or ornithurine. If the dating is confirmed, it lived at the same time as a primitive, *Archaeopteryx*-like bird—and just an instant, geologically speaking, after *Archaeopteryx* itself. That could shove *Archaeopteryx* and another large group of primitive birds off the evolutionary branch that led to modern birds; it could even imply an earlier origin for all birds, perhaps before their putative dinosaurian ancestors. "It shows that there was a dichotomy, and that *Archaeopteryx* and most of the other early birds were a side line of avian evolution," says University of North Carolina ornithologist Alan Feduccia, co-author of the paper with paleontologists Lianhai Hou and Zhonghe Zhou of the Chinese Academy of Sciences, and Larry Martin of the University of Kansas.

But other paleontologists think Feduccia is out on a limb. Although few argue that *Archaeopteryx* itself led directly to modern birds, many think that a related primitive group called the opposite birds are close kin to modern birds. What's more, says Yale University paleontologist John Ostrom, "the dating [of the Chinese fossils] is controversial." If the new fossils are substantially younger than *Archaeopteryx*, as other dating work suggests, then they may offer little new insight into the origins of birds, says paleontologist Luis Chiappe of the American Museum of Natural History in New York.

Reconstructing the bird family tree has been difficult because of a dearth of fossils after *Archaeopteryx*. But new finds in the past 5 years have revealed unexpected diversity in early birds starting at about 135 million years ago. Most of these, the dominant birds of the Mesozoic, were enantiornithurines, or "opposite" birds, so named because three bones



Which feet first? Modern birds have the foot bones fused from the bottom up *(right)*; in opposite birds, the fusion is top down *(left)*.

of their feet are partially fused from the top down, rather than from the bottom up as in modern birds (see figure). In contrast, the first few fragmentary remains that might be ornithurines didn't appear in the fossil record until later, about 120 million years ago.

Until recently, many paleontologists thought that *Archaeopteryx* itself gave rise to opposite birds, which in turn gradually evolved into modern birds. That view has faded, but Chiappe and others still hold that opposite and modern birds are closely related sister taxa, with a recent common ancestor that lived at about the time of *Archaeopteryx* or a bit earlier; this scenario allows enough time for birds to descend from Jurassic dinosaurs.

Feduccia and his colleagues now challenge that view with fossils of a bird the size of a sparrow, called *Liaoningornis*. The specimen, unearthed by a farmer in the Yixian formation in northeastern China's Liaoning Province, lacks a skull but includes a nearly complete skeleton with foot bones and a keeled sternum that resemble those of modern birds. Yet the Chinese scientists cite radiometric dates of 137 million to 142 million years for the volcanic rock of the Yixian formation, which would make the bird almost as old as *Archaeopteryx*. And the same beds also yielded a magpie-sized primitive bird called *Confuciusornis*, which shares many traits with both *Archaeopteryx* and opposite birds. Indeed, these rich beds also produced a controversial "feathered" dinosaur (*Science*, 1 November 1996, p. 720).

According to Feduccia and Martin, the discoveries imply that by the time of *Archaeopteryx*, birds had already diverged into two lineages and had a rich history that is missing from the fossil record. One lineage led to modern birds. Another led to *Archaeopteryx* and the opposite birds, which they view as sister taxa, closely related to each other but distinct from the line that led to modern birds. And both these bird lineages must have descended from a much earlier ancestral bird. Feduccia reckons that the first bird must have lived about 76 million years before the birdlike dinosaurs of the Cretaceous —a fact that he says raises questions about the dinosaurian origins of birds.

However, not everyone agrees with those dates. New argon-argon dates on the volcanic rock and sediment in the Yixian formation, presented at the recent Society of Vertebrate Paleontology meetings in New York, date the birds at only about 121 million years, says University of Toronto physicist Derek York, a co-author on the poster at the meeting. If so, then it's possible that Chiappe is right: Some unknown bird that lived about the time of *Archaeopteryx* underwent rapid evolution and gave rise to both opposite and modern birds, as represented by *Confuciusornis* and *Liaoningornis*.

Feduccia's co-author Martin questions the new argon-argon date, noting that arthropods and pollen in the Yixian formation are characteristic of the Late Jurassic about 140 million years ago. Feduccia simply says that the dating controversy is overblown: "Whatever the date is, we're getting both types of birds shortly after *Archaeopteryx*"—making the stunningly successful modern birds early birds indeed.

–Ann Gibbons