PALAEONTOLOGY

An icon knocked from its perch

As sesquicentennial celebrations commemorate the discovery of *Archaeopteryx* as a historical symbol of evolution and the oldest fossil bird, new work shakes the dinosaur family tree — and our view of this icon. SEE ARTICLE P.465

LAWRENCE M. WITMER

It's been a good run for *Archaeopteryx*. For the past 150 years, the famous feathered fossil species from Bavaria in Germany has been a symbol of evolution, a textbook example of a transitional fossil and, above all, the oldest and most primitive bird. On page 465 of this issue, however, Xu and colleagues[1] present a newly discovered *Archaeopteryx*-like species named *Xiaotingia zhengi* that rearranges the branches on the phylogenetic tree of bird-like theropod dinosaurs, knocking *Archaeopteryx* (Fig. 1) off its celebrated perch and moving it and its kin into the great unwashed ranks of 'non-avian' dinosaurs. This finding is likely to be met with considerable controversy (if not outright horror), in part because of the historical and sociological significance that *Archaeopteryx* has held, but also because it may mean that much of what we thought we knew about the origin and early evolution of birds will need to be re-evaluated.

The fossils of *Xiaotingia* were found in Liaoning Province, China, where so many other spectacular specimens of feathered dinosaurs and early birds have been discovered[2]. The precise provenance of the specimen is a little uncertain, because it was purchased from a dealer, but all indications are that it comes from the Tiaojishan Formation, which dates to the Late Jurassic, some 155 million years ago. The chicken-sized skeleton, splayed out on a slab of shale and surrounded by a halo of feather impressions, isn't as striking as the specimens of *Archaeopteryx*, but its constellation of subtle bony bumps and grooves makes *Xiaotingia* a game-changer.

The main players here are an assemblage of bird-like dinosaurs — oviraptorosaurs and deinonychosaurs (including troodontids and dromaeosaurids) — and dinosaur-like birds that belong to the avialans. Deinonychosaurs and avialans together comprise a group known as Paraves, with oviraptorosaurs being a bit more distantly related (Fig. 2). As more fossils of basal members of each of these groups have been collected, distinctions between the groups have predictably blurred, and some species have bounced around from group to group. For example, *Anchiornis*, which recently made headlines for its colourful plumage[3], was originally regarded as a basal avialan[4], then a basal troodontid[5], and is now considered an archaeopterygid[1].

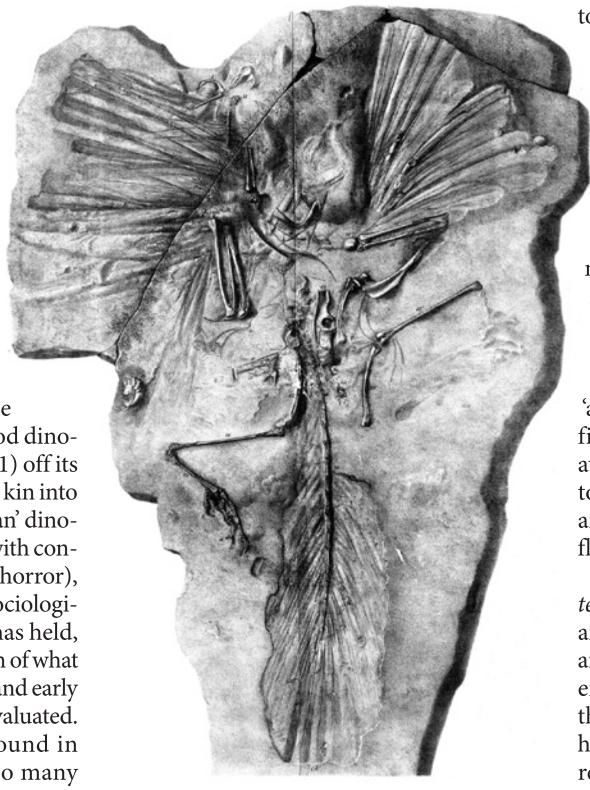

Figure 1 | *Archaeopteryx*. For 150 years, the Jurassic fossils of *Archaeopteryx* have been a textbook example of an evolutionary transition. From Plate 1 in ref. 11.

Enter *Xiaotingia*. When Xu *et al.*[1] ran a phylogenetic analysis combining the attributes of *Xiaotingia* with those of *Archaeopteryx*, other basal avialans, deinonychosaurs, and oviraptorosaurs, not only did *Xiaotingia* and *Anchiornis* cluster with *Archaeopteryx*, but these archaeopterygids now were yanked out of Avialae and placed in Deinonychosauria (Fig. 2). In other words, *Archaeopteryx* was no longer a bird. Surprised by this outcome, the authors re-ran the analysis with identical parameters, but this time omitting *Xiaotingia*. The result was that *Archaeopteryx* was restored to Avialae as the most basal bird. This experiment affirmed how crucial *Xiaotingia* is to understanding the evolution of advanced theropods.

It may seem heretical to say that *Archaeopteryx* isn't a bird, but this idea has surfaced[6] occasionally since as far back as the 1940s. G. S. Paul has been the most vociferous advocate, even going so far as to make dromaeosaurs a subfamily within the Archaeopterygidae[7], thus moving *Archaeopteryx* well outside the birds. Moreover, there has been growing unease about the avian status of *Archaeopteryx* as, one by one, its 'avian' attributes (feathers, wishbone, three-fingered hand) started showing up in non-avian dinosaurs. Perhaps the time has come to finally accept that *Archaeopteryx* was just another small, feathered, bird-like theropod fluttering around in the Jurassic.

But why is this such a big deal? *Archaeopteryx* has always been something of a celebrity and has monumental historical, sociological and even political importance. It was discovered, with perfect timing, in mid-1861, less than two years after Darwin's *Origin of Species* hit the bookstalls[8]. With its blend of avian and reptilian characteristics (not to mention the charismatic beauty of the fossils themselves), *Archaeopteryx* was seemingly the ideal evolutionary intermediate, instantly entering the debates over evolution in Victorian England and elsewhere, and gaining prominence in textbooks.

Given this iconic role, *Archaeopteryx* has also been in the cross-hairs of creationists, and remains a lightning rod for political debates and legal proceedings about teaching evolution in schools. Of course, Xu and co-workers' finding only deepens the impact of *Archaeopteryx* by highlighting the rich evolutionary nexus of which it is a part, but how the ever-clever creationist community will 'spin' it remains to be seen.

Politics aside, the historical importance of *Archaeopteryx* stands, even if we need to add the footnote that current evidence no longer regards it as the oldest bird. The impact of losing *Archaeopteryx* from the avian clan is, nevertheless, likely to rock the palaeontological community for years to come simply because, for the past century and a half, these familiar fossils have guided almost all scientific thought about the beginnings of birds. The late John Ostrom, the most influential modern worker on avian origins, began his seminal 1976 article[9], itself entitled '*Archaeopteryx* and the origin of birds', with the statement, "The question of the origin of birds can be equated with the origin of *Archaeopteryx*, the oldest known bird." Indeed, virtually all our notions about early avian evolution have been viewed through the lens of *Archaeopteryx*. Hundreds of publications (including several of my own) draw on the structure of *Archaeopteryx* to formulate and evaluate hypotheses about birds. Some published phylogenetic analyses have even used *Archaeopteryx* as the sole representative of birds. To what species do we now turn to ground our understanding of early birds?

According to Xu and colleagues' analysis[1], the most basal fossil birds are forms such as *Epidexipteryx*, *Jeholornis* and *Sapeornis*, all of which were named in the past decade and so comprise new territory even for specialists. Clearly, without the safety net of good old *Archaeopteryx* at the base of the birds, we've got some fresh work to do.

Once we stop whining, of course, we can see that this exciting finding actually resolves some incongruities. For example, recent work[10] suggests that herbivory may have been common among advanced bird-like dinosaurs, with carnivory potentially being secondarily evolved in the deinonychosaurs. Moving archaeopterygids and their carnivorous skulls out of birds and into the carnivorous deinonychosaur group makes the herbivorous oviraptorosaur-like skulls of basal birds more consistent with this new hypothesis of widespread herbivory (Fig. 2).

In truth, this chapter of the scientific story is just beginning. Just as *Xiaotingia* moved *Archaeopteryx* out of the birds, the next find could move it back in — or to somewhere else within this fuzzy tangled knot that makes up the origins of birds and bird-like dinosaurs. That said, during this sesquicentennial anniversary of *Archaeopteryx*, which is being honoured with exhibits and commemorative coins, the bitter irony may be that it may not have been the bird we've always thought it was. But *Archaeopteryx* will remain an icon of evolution, perhaps even more so now, providing compelling evidence that, as we should expect, evolutionary origins are rather messy affairs. ■

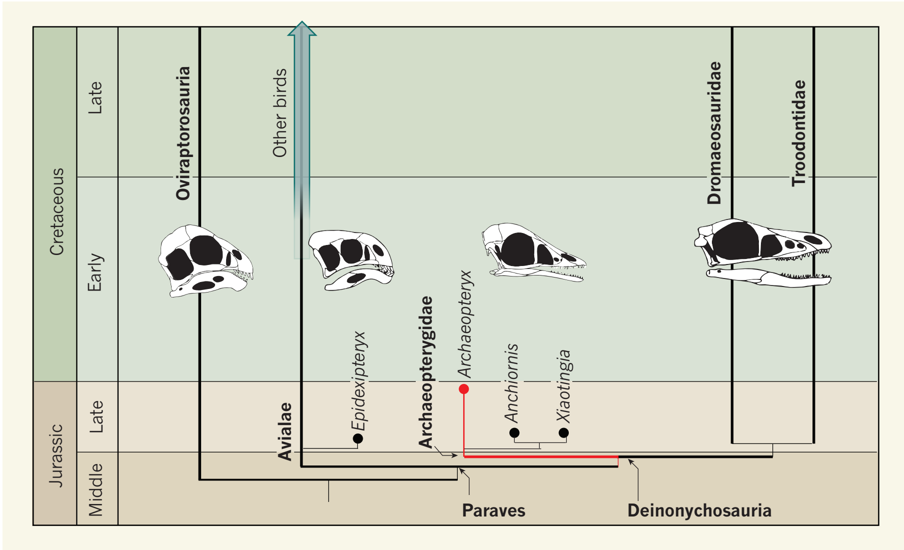

Figure 2 | A cluster of feathered dinosaurs. *Archaeopteryx* has historically been regarded as the most basal bird (avialan), but the discovery of the closely related *Xiaotingia* led Xu *et al.*[1] to pull these archaeopterygids out of avialans (birds) and into deinonychosaurs along with dromaeosaurids and troodontids. This new grouping better accounts for the evolution of feeding strategies among bird-like dinosaurs. Previous research[10] suggested that herbivory was common among this group, as reflected in the tall, boxy skulls of oviraptorosaurs and basal avialans such as *Epidexipteryx*. The triangular, sharp-toothed skull of *Archaeopteryx* was incongruous among basal avialans, but fits better among the carnivorous dromaeosaurids and troodontids.

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PRECISION MEASUREMENT

Exciting antiprotons

Shining light on an antiproton masquerading as an electron in a helium atom is a rich source of physics. An approach that brings this technique to unprecedented precision will allow new tests of matter–antimatter symmetry. **SEE LETTER P.484**

MIKE CHARLTON

In a 1991 News & Views article[1] on the ingenious means by which positrons, the antiparticle counterpart of electrons, were used in materials science, John Maddox, the then editor of *Nature*, asked: "Can any antiparticle make a probe?" What prompted the question was the discovery[2] that a few per cent of the antiprotons injected and stopped in liquid helium were trapped in long-lived (metastable) states, with lifetimes of several microseconds. Twenty years down the line, Maddox's poser can be answered with an unequivocal 'yes'. The three-body atomic system that is formed when an antiproton replaces one of the electrons in a helium atom has proved a superb probe for fundamental physics.

In the latest advance, Hori and co-workers[3] (page 484) describe a trick that has enabled transitions between selected energy levels of the antiprotonic helium to be measured with unprecedented precision. The bottom line is that these measurements, when combined with theory[4], have allowed, among other things, a more accurate value of the antiproton-to-electron mass ratio to be determined in order to compare it with the proton equivalent.

The source of the antiprotons is the Antiproton Decelerator located at CERN, the European particle-physics laboratory near Geneva in Switzerland. This unique machine provides pulses of antiprotons every hundred seconds or so. After deceleration, the antiparticles are injected into a cell containing helium