

THE GROUND BREAKER

AS HE REVOLUTIONIZES IDEAS ABOUT DINOSAUR EVOLUTION,
XING XU IS HELPING TO MAKE CHINA INTO A PALAEOLOGICAL POWERHOUSE.

BY KERRI SMITH

Palaentologist Xing Xu bends low over a beautifully preserved specimen of the ancient bird species *Sapeornis*, entombed in a glass museum cabinet in Shandong Province, China. The bird's spindly legs stretch as if it were about to stride forward, even though the creature has been dead for more than 110 million years. From its chicken-sized body juts a fine neck, a delicate skull and the clear imprint of a long, jaunty tail feather — something never seen before in this species.

Sapeornis is one of hundreds of plumed specimens pouring out of fossil beds in China — most notably out of the rock formations in Liaoning Province, northeast of Beijing. Some of the Liaoning fossils are the earliest known birds. Others are feathered dinosaurs,

Xing Xu stands among the remains of duck-billed dinosaurs in Zhucheng, China.

LOU LINWEI

the group that spawned birds millions of years before the age of *Sapeornis*. Together, they are among the most important finds in dinosaur palaeontology in the past century.

Xu is at the centre of that bonanza. He is “the go-to man in China for anything people want to know about dinosaurs”, says Paul Barrett, who studies dinosaurs at the Natural History Museum in London and first met Xu in the 1990s, when both were graduate students. Xu, who is based at the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) in Beijing, has named 60 species so far — more than any other vertebrate palaeontologist alive today. And he is only 43 years old.

In describing the flock of feathered fossils, Xu has helped to show that birds arose from dinosaurs, ending decades of debate. Along the way, he has shed light on the origins of feathers and flight. And he has bucked 150 years of received wisdom by declaring that the fabled genus *Archaeopteryx* is not the oldest known bird, but rather belonged to a group of dinosaurs removed from the avian line¹. “He has patience and persistence — and an audacity when scientific evidence calls for it,” says Zhe-Xi Luo, who studies fossil mammals at the University of Chicago in Illinois.

Even as he unveils new species at a break-neck pace, Xu is concerned about the future of palaeontology in China and the commercialization of fossils. Many of the feathered fossils from Liaoning are dug up by local farmers tending their fields, who try to sell them to the highest bidder. This fossil ‘grey market’ — it is technically illegal to sell fossils in China, but the practice continues openly — encourages fakery and causes specimens to disappear into private collections. By cultivating a vast network of contacts at important fossil sites in Liaoning and elsewhere, Xu has laboured to ensure that scientists gain access to the best specimens. It’s a job that requires hard work and luck, he says. “When I started my career, I never expected that I would have so many discoveries.”

DINO DISNEY

Nobody knows what happened about 80 million years ago near what is now the town of Zhucheng in Shandong Province, but it must have been disastrous. On the outskirts of the city, about an hour’s flight south of Beijing, hundreds of bones litter a 300-metre stretch of hillside. Palaeontologists have been finding dinosaurs near Zhucheng for decades, but in 2008 local farmers unearthed a large community of duck-billed dinosaurs and others that had apparently died en masse.

Xu was called in to investigate and he is now studying a possible new species of ceratopsian — herbivorous beaked dinosaurs — recovered from the fossil bed. He is also acting as scientific consultant to local administrators,

who want to build a dinosaur theme park in Zhucheng. During a visit to the site in June, Xu had hoped to do research, but he ended up correcting display captions and reading through proposals for the park. “In terms of scale it may be comparable to Disneyland,” says Xu, a hint of trepidation in his voice.

Fossils are a thriving business as well as a science in China, and palaeontologists often have to negotiate with local prospectors and directors of museums and tourism bureaux to gain access to fossil sites and specimens. Despite Xu’s boyish appearance, he is a dexterous diplomat and has managed to arrange for the most scientifically interesting specimens to cross his desk, wherever they are found.

Thanks to those arrangements, Xu has had a bounty of fossils to work on, particularly from Liaoning. The creatures unearthed there are remarkably well preserved, perhaps because they were entombed quickly during volcanic eruptions and mudslides between 160 million and 120 million years ago. The rocks record fine details including the imprints of feathers, which allowed Xu to determine² that a fierce 9-metre-long tyrannosaurid, which he named *Yutyranus*, had a coat of long feathers (see ‘Xing Xu’s feathered friends’). One of Xu’s favourite Liaoning fossils, *Microraptor*, is one of the smallest known dinosaurs not on the avian line. From the imprint of feathers, Xu and his colleagues concluded³ that *Microraptor* had four wings — one on each arm and leg — and could probably glide. From other Liaoning specimens, he has established⁴ that some feathered dinosaurs slept curled up, just like birds.

“MY EXCITEMENT IS PROPORTIONAL TO THE INFORMATION YOU GET. AND THOSE WERE REALLY EXCITING FOSSILS.”

When he can find the time, Xu does fieldwork of his own (see ‘Dinosaur hunting grounds’). He led teams to three sites this summer. Near the northern Chinese town of Lingwu, the excavations turned up a new sauropod — a dinosaur from the same group as *Diplodocus*. In the autonomous region of Inner Mongolia, the Xu group found a new type of bird and what may be a previously unknown theropod — the dinosaur lineage that led to birds. At another northern site, he uncovered a collection of beaked dinosaurs.

To power this dinosaur-discovery factory, Xu runs a lab of 14 people, including five students, seven preparators who carefully separate the fossils from the surrounding rock, one artist and a photographer. Those resources have been known to induce jealousy in

Western palaeontologists. The Natural History Museum in London, for example, has just two full-time preparators for about 20 palaeontology curators and researchers, says Barrett.

Xu didn’t set out to be a palaeontologist; in fact, he had no idea what a dinosaur was until he entered university. He was born in the poor Western province of Xinjiang in 1969, a few years after his parents relocated there as part of a Cultural Revolution development initiative in which educated couples were forced to move to rural provinces.

He excelled in school and in 1988 earned a place at Peking University in Beijing, the nation’s premier university. Xu wanted to study economics, but at the time students had no choice in their degrees. For reasons that are unclear to him, he was obliged to study palaeontology.

LATE STARTER

Xu’s interest in the subject picked up only when he reached the third year of a master’s degree at the IVPP. He was studying two specimens that his adviser, Xijin Zhao, had discovered in the 1960s and 1970s and had not found time to analyse fully. They turned out to be the earliest examples of ceratopsians, pushing the record of this group back by up to 30 million years, from the early Cretaceous period, which started 145 million years ago, to the middle or late Jurassic period⁵. “My excitement [over a fossil] is proportional to the information you get from it,” says Xu. “And those were really exciting fossils.”

Xu’s timing was perfect. While he was working on his master’s thesis, the trickle of dinosaur species turning up in China grew to a deluge. Funding for palaeontology was increasing; farmers in Liaoning started recognizing the value of the fossils they sometimes found; and a burst of construction meant that new fossils were being unearthed more frequently. As a budding dinosaur palaeontologist, Xu was well placed to study some of those specimens.

However, fortuitous timing can explain only a portion of Xu’s productivity. A large part comes from his legendary work ethic. “If I want to learn something I put all my time into it,” says Xu. He currently has more than 20 manuscripts in draft form, including one on the *Sapeornis* specimen from the Shandong Tianyu Museum of Nature. He estimates that there are eight or nine new species among the crop of fossils awaiting publication.

Even away from his office, any spare moment is filled with talk of projects. Outside the Tianyu museum, Xu chats to a colleague about *Microraptor* and — to make an anatomical point — starts drawing a diagram of the creature’s feathers in the dust on a nearby car.

Xu has an international outlook that also contributes to his success. From the start of his career, he has done what has not come naturally to many Chinese palaeontologists

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— building up a fat book of contacts in the United Kingdom and the United States, and publishing much of his work in English in international journals. Playing to a tougher international audience was “really important for my career”, says Xu. Chinese journals, he adds, don’t require the same level of critique and peer review as international publications.

Luo says that Xu is one of only a few palaeontologists in China to embrace cladistics — a process for determining evolutionary relationships by analysing the features that groups share. Western researchers and international journals have been using cladistics for more than two decades, but it has been slow to catch on in China.

Within his own country, Xu crosses boundaries between the academic and commercial sectors. For example, he has forged a close relationship with Xiaoting Zheng, the former head

of a local state-owned gold mine who is now a keen amateur fossil collector, a budding palaeontologist and director of the Tianyu museum. In his museum, Zheng has accumulated one of the largest assemblages of feathered dinosaur fossils in the world. Over the years, Xu has been teaching him what to look out for in his purchases and has analysed some of the acquisitions. The two make a formidable team.

FEATHERS FLYING

Last year¹, Xu made a big splash with a specimen from the Tianyu museum’s collection: a small feathered dinosaur that he named *Xiaotingia zhengi* to honour Zheng. The creature had a shallow snout, a distinctive skull shape and other features that led Xu and his colleagues to place it as a close relative of *Archaeopteryx*. That animal has long been regarded as the oldest known bird, but Xu and his

colleagues performed a cladistic analysis that knocked *Archaeopteryx* from its special perch on the bird lineage, relegating it to a different branch along with a host of other feathered dinosaurs. That study has met resistance from some other palaeontologists, who question the strength of the cladistic analysis and say that the evolutionary relationships will remain unclear until more early birds and their close relatives are discovered.

The Liaoning fossils have led Xu to make other bold proposals about the origins of flight. The discoveries of *Microaptor* and *Anchiornis*, another four-winged dinosaur, led Xu to argue⁶ that the four-winged trait was not an evolutionary dead end, as had been previously assumed, but could actually have been the transitional step between dinosaurs and birds.

The feathered dinosaur fossils have also provided some of the first hard evidence for when

XING XU'S FEATHERED FRIENDS

Fossils found in Liaoning in northwestern China show that many dinosaurs in the late Jurassic and early Cretaceous periods had feathers. The exceptional specimens have transformed ideas about theropod dinosaurs and the birds that evolved from them.



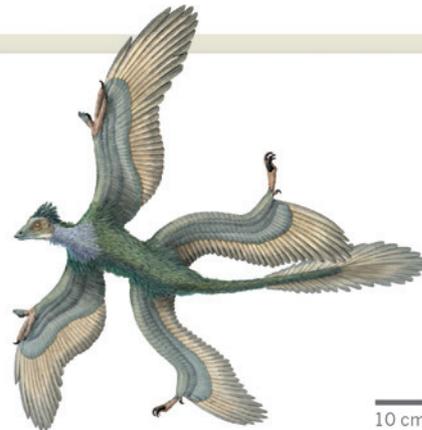
XIAOTINGIA ZHENGII

Late Jurassic (160 million to 145 million years ago)
The 30-centimetre-long *Xiaotingia* had feathers and other features resembling those of *Archaeopteryx*, often considered the earliest bird. Xu has proposed that both belonged to a group of non-avian dinosaurs, closely related to but distinct from birds.



ANCHIORNIS HUXLEYI

Late Jurassic (160 million to 145 million years ago)
An exquisitely preserved specimen of the dinosaur *Anchiornis* helped Xu and his colleagues pin down the timing of the transition from dinosaurs to birds. Its long feathers demonstrated how complex early plumage could be.



MICROAPTOR GUI

Early Cretaceous (145 million to 100 million years ago)
Although not a bird, the tiny dinosaur *Microaptor* had feathers on its arms (see below) and on its legs, and it may have flown.



YUTYRANNUS HUALI

Early Cretaceous (145 million to 100 million years ago)
This 9-metre-long long predator provided evidence that even some big dinosaurs had feathers. Three specimens were found — two juveniles and an adult — with feathers in various locations, including the hip, neck and back.

X. ZHENG: XING LIDA/LIU YI; A. HUXLEY: J. T. CSOTONYI/SPL; M. GUI RECONSTRUCTION: P. SLOAN; M. GUI PHOTOGRAPH: REF. 3; T. HUALI: BRIAN CHOO

and why feathers evolved. “For most of the past century, the classic issue in feather evolution was that the fossil record told us essentially nothing,” says Richard Prum, who studies the evolution of birds at Yale University in New Haven, Connecticut. “What’s happened with the Liaoning formation has been a totally new chapter.”

In the past, palaeontologists had presumed that when feathers first arose, they helped bird ancestors to fly. But on the basis of his discoveries, Xu makes the controversial argument that most dinosaurs probably had at least a smattering of plumage, which would mean that feathers originally served other functions, such as attracting mates or insulating against the cold.

ROLE MODEL

With his extraordinary track record, Xu brings to mind the prodigious US palaeontologists Othniel Marsh and Edward Cope, who discovered dozens of dinosaurs in the late nineteenth century in a frenetic competition that became known as the bone wars. But whereas those Victorian fossil hunters made frequent errors, such as giving new names to species that had already been described, Xu is a careful researcher who does not rush into print. His published record of new species has rarely been challenged, says Mike Benton, a palaeontologist at the University of Bristol, UK, who has analysed the accuracy of dinosaur researchers.

Xu would like to see Chinese science as a whole become more careful. “Chinese culture is a problem for science because it’s not logical enough,” says Xu during a trip this summer, as his driver gaily overtakes on the wrong side of the road. “Traditionally people don’t like to criticize, either. For peer review you have to criticize in some way...” He breaks off mid-sentence to answer a phone call in Mandarin for a few minutes, before resuming exactly where he left off “... but here in China we don’t have a real peer-review system.”

Another problem hanging over Chinese palaeontology is fakery. Xu is keenly aware of it. In 2000, he helped⁷ to unmask one of the biggest hoaxes in a generation: a composite specimen named *Archaeoraptor*, made up of the upper body of an ancient bird and the tail of the dinosaur *Microraptor*. Scientists are getting better at spotting fakes, says Xu, but they do still crop up, because poor farmers know that they can sell the most unusual fossils to museums or institutes for hefty sums. “We have the greatest resources in palaeontology now,” says Zhonghe Zhou, director of the IVPP, “but on the other hand, the destruction of localities, the faking — those kinds of things are often the most severe. The law isn’t good enough.”

Xu worries about the future of his profession, particularly the next generation of scientists. His current students aren’t showing the

DINOSAUR HUNTING GROUNDS

Rich deposits of dinosaur fossils are scattered around China. Xing Xu has excavated or studied many of key finds emerging from those sites.



dedication that their boss would like. “They don’t work as hard as me,” he says. “Maybe I ask too much, maybe that’s my problem.” Qing-Jin Meng, director of the Beijing Museum of Natural History, says, “Excellent palaeontologists [such as Xu] are hard to find.” Part of the problem may be the globalization of Chinese palaeontology, he adds. “Many students who have great potential have gone to the United States and European countries to study.”

Xu says that if only he could find the time, he would like to write articles about how to improve Chinese science. But so far he has published only one blog post in Mandarin.

HE IS THE GO-TO MAN IN CHINA FOR ANYTHING PEOPLE WANT TO KNOW ABOUT DINOSAURS.

“Honestly, I don’t like it much. I’d rather do science,” he says.

Xu’s packed schedule can be hard on his family — his wife Zhonghia Zhou, who is a secretary at the Institute for Geology and Geophysics in Beijing, and their two boys, aged 7 and 12. “My wife complains because the kids are growing up,” confesses Xu. “She says they need a male example. And I thought, yeah, that’s important.”

So in the past couple of years he has tried to spend more time at home, helping with homework, playing table tennis with his wife and taking his family on days out to Beijing’s parks. Even the director of the IVPP recognizes a candidate for burn-out when he sees one: “He should slow down a bit!” says Zhou. “You can’t study everything — you need time for hobbies.” To that end, Xu and Zhou sometimes

play badminton on the court installed in the entrance hall of the IVPP.

It is unlikely that Xu’s hobbies will eat into his prodigious output too much. Back in his office in Beijing after the trip to Zhucheng, Xu rummages through the floor-to-ceiling cupboards lining two walls. He pulls out slabs of rock, pointing out salient features and clues that he might have an unknown species on his hands.

More than setting records by finding new creatures, Xu is interested in asking and answering questions about a far-gone era, when his country was filled with a dizzying array of feathered dinosaurs and birds. He is keen, for example, to continue exploring how non-avian dinosaurs developed feathers and whether the plumage differed from that of modern birds. As he looks over the fossils in his office, Xu’s eyes glint with a blend of tiredness and excitement.

Luo, who has watched Xu’s career take off, sees no end to the potential discoveries. “Fossils are silent,” says Luo. “It takes an insightful palaeontologist to tell their story, and Xu Xing is a fantastic storyteller.” ■

Kerri Smith is podcast editor for *Nature* in London.

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