THE FEATHERED DINOSAURS OF CHINA

TEXT
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PHOTOGRAPHS
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Nelle pagine precedenti, ricostruzione pittorica di ambiente con Sinosauropteryx prima. *(Disegno di Michael Skrepnick).*

Previous pages, pictorial reconstruction of the Sinosauropteryx prima *in its habitat (Drawing by Michael Skrepnick).*

Sotto, l'autore di questo articolo, Philip J. Currie, ha scoperto recentemente (marzo 2000), in Patagonia, il più gigantesco dinosauro carnivoro conosciuto.

Below, the author of this article, Philip J. Currie, recently found the largest known carnivorous dinosaur (Patagonia, March 2000).

Pagina accanto, il più piccolo esemplare noto di Sinosauropteryx prima, *conservato presso l'Istituto di Geologia e Paleontologia di Nanjing. Si osservi l'aureola di "protopenne" intorno al corpo.*

Opposite, smallest known specimen of Sinosauropteryx prima *in the Nanjing Institute of Geology and Paleontology. Note the halo of "protofeathers" around the body.*

Almost a century and a half ago, the first fossil feathers were found on a 150 million year old bird from Solnhofen in Germany. The bird was given the name *Archaeopteryx*, which means "old wing". Unlike modern birds, it had teeth in its jaws, three clawed fingers on each of its hands, and a long bony tail. Although these are not characters found in any modern birds, the long feathers on the arms helped to form wings and clearly showed its relationship to modern birds. The combination of reptilian and bird characters immediately suggested that *Archaeopteryx* was "the missing link" between reptiles and birds. The similarities between the earliest bird and *Compsognathus*, a chicken-sized, meat-eating dinosaur, were particularly striking. Both of these animals were recovered from rocks of the same age and were from the same region of Germany. They were so similar that when a specimen of *Archaeopteryx* was found later lacking its feathers, it was misidentified as *Compsognathus*.

In 1868, Thomas H. Huxley from England realized that dinosaurs were very closely related to birds. This was not long after the publication of Charles Darwin's famous book - "On the Origin of Species". For the rest of the nineteenth century, most scientists accepted the idea that birds evolved from dinosaurs. However, early in the twentieth century a Danish scientist by the name of Gerhard Heilmann did a thorough analysis of the evidence in his book on the "Origin of Birds". He concluded that dinosaurs were closely related to birds, but could not be ancestors because they lacked the wishbone. The wishbone, so familiar to those of us who like to eat chickens, turkeys and other birds, is technically known as the clavicles. This ancient bone is found in almost all animals with backbones, from fish to men. But dinosaurs had supposedly lost the clavicles, and Heilmann pointed out that they could therefore not have given rise to birds, which still have clavicles. Generally once a bone is lost, it cannot be reacquired. Everyone accepted Heilmann's reasoning, and for most of this century the general wisdom has been that dinosaurs are not the direct ancestors of birds, even though they share a common ancestor.

What Heilmann did not know was that in 1923 a dinosaur with a wishbone was found in Mongolia. Unfortunately, the wishbone of Oviraptor was misidentified for half a century. The wishbones of other meat-eating dinosaurs also went unnoticed

A New Gigantic Dinosaur Is Discovered

By The Associated Press

Scientists have discovered the bones of what could be the largest meat-eating dinosaur ever to walk the earth, a needle-nosed, razor-toothed beast that may have been more terrifying than Tyrannosaurus rex.

A team of researchers from Argentina and North America unearthed the fossilized bones of as many as six of the previously unknown species in Patagonia, a largely barren region on the eastern slopes of the Andes in southern South America.

The discovery of the predators' graveyard challenges the theory that the largest meat-eaters were loners and raises the possibility that they lived and hunted in packs, which would have made them even more terrifying to their prey.

"You always think of these things as being solitary — now we know they traveled in packs," said Dr. Philip J. Currie, one of

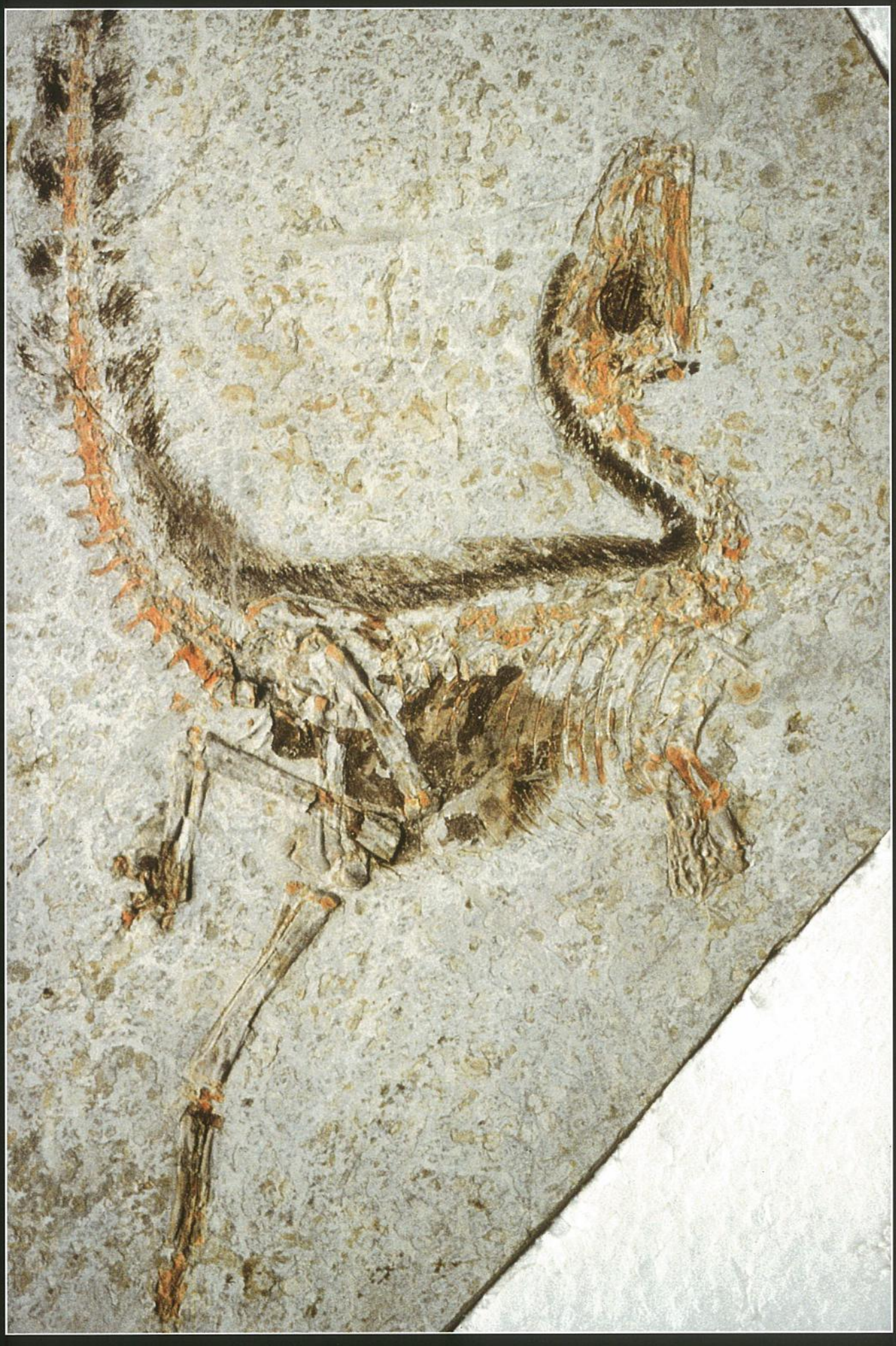
Associated Press

Dr. Philip J. Currie and a colleague in Argentina have discovered the bones there of what could be the largest meat-eating dinosaur.

"I think it would look just as nasty, if not worse," Dr. Currie said. "This guy has a long snout, long skull,

dinosaur was not what made it scientifically interesting.

"It's that we've got a new spe-



Alcuni sassi trovati nello stomaco del Caudipteryx zoui *e conservati al Museo Geologico Nazionale della Cina. Talvolta i dinosauri e gli uccelli ingurgitavano sassi per triturare il cibo nello stomaco.*

Stones inside the stomach of Caudipteryx zoui *in the National Geological Museum of China. Dinosaurs and birds sometimes swallow stones to help them grind up food in the stomach.*

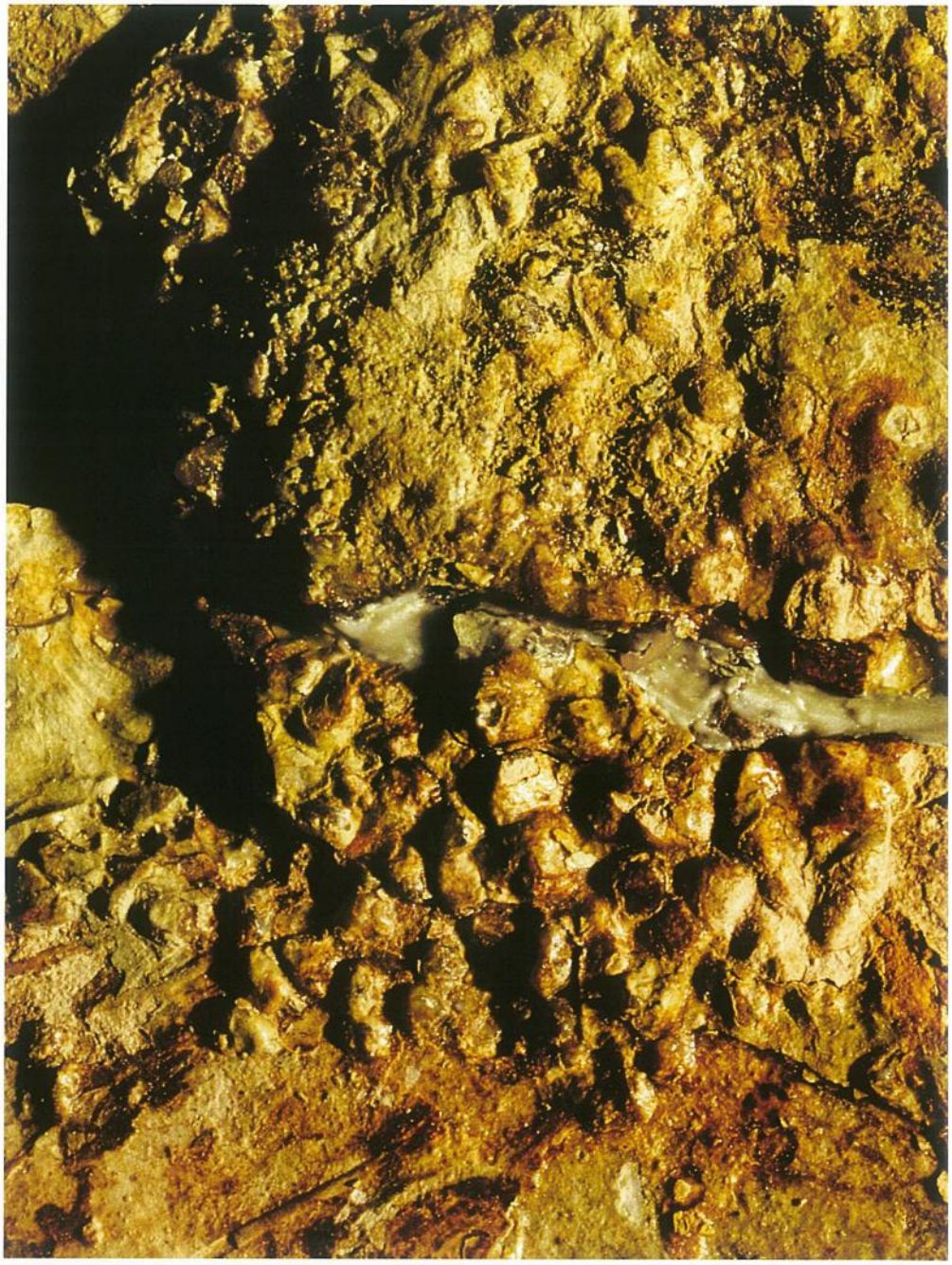
because they were small, and because nobody expected them to be there. After the wishbone of *Oviraptor* was identified correctly in 1976, it was subsequently identified in the 1990s in many other meat-eating dinosaurs, including the mighty tyrannosaurs (*Tyrannosaurus rex, Albertosaurus sarcophagus, Gorgosaurus libratus*, and others).

Many other lines of evidence suggested to scientists that birds had arisen from dinosaurs after all. But the theory was controversial, and was hotly disputed by several scientists. One even said that the only proof that would be convincing would be the discovery of dinosaur fossils with feathers.

In 1994, farmers in the province of Liaoning in northeastern China discovered a way to supplement their low incomes. Working in pits in the hillsides, they cracked open tons of rocks to find fossils that could be sold to museums and tourists. The fossils that commanded the highest prices were of a bird known as *Confuciusornis.*

When *Confuciusornis* was flying around northeastern China 140 million years ago, the climate was warm, and the vegetation grew densely around the margins of a great system of lakes. There were volcanoes in this area, and when they erupted, the lava and ash killed many animals. Their bodies either fell into the lakes directly, or were carried there by the many rivers that flowed through the forests. The volcanic ash was fine enough to preserve the smallest details of the feathers, and it chemically stopped bacteria from destroying them. These unique circumstances allowed the exquisite preservation of the Liaoning fossils.

One day, Li Yinfang broke open a slab of rock and was amazed to see the fossil of a long-tailed, chicken-sized animal surrounded by feathers. He realized that this was not *Confuciusornis*, and it reminded him of pictures of *Archaeopteryx* from his schoolbooks. He knew he had discovered something very important. The specimen had been split right down the middle – the right half was on one piece of rock, and the left side was on another. He decided that he could make more money if he sold each half separately. When we met him in Liaoning in 1997, Li Yinfang had a twinkle in his eye as he told how he sold part of the



specimen to the National Geological Museum of China, and the other half to the Nanjing Institute of Geology and Palaeontology.
The first feathered theropod had been shown to me in Beijing (China) in September 1996. My wife and I had been invited to visit Dr. Ji Qiang, the director of the National Geological Museum of China in Beijing, who was lucky enough to have this delicate little fossil in his museum's collections. Seeing that specimen for the first time was one of those moments in life that I would love to experience again and again.
Later that year, Ji Qiang and his student Ji Shu-an gave it the name *Sinosauropteryx prima*, which means "First Chinese Dragon Feather". The first English language paper was published in the scientific journal "Nature" early in 1998.
Sinosauropteryx was a small flesh-eating dinosaur (theropod), the size of a turkey. The scientific description was based on a nearly complete skeleton, which are very rare for small dinosaurs. The tail is very long in *Sinosauropteryx*, and consists of 64 vertebrae, which is more than in any other known flesh-eating dinosaur.
The arms are very short but very strong. Imagine, if you can, having a claw on your thumb that is as long as your upper arm!
The most extraordinary feature of the *Sinosauropteryx* specimens is their feather-like body covering. They are covered by thin filaments, mostly along the neck, back and tail. The filaments are probably made of keratin, which is the same material that composes the hair of mammals, the beaks and feathers of birds, and the "fingernails" of all animals that have claws. Modern bird feathers consist of a shaft with barbs that are held together by barbules and hooklets. The body covering of *Sinosauropteryx* seems to consist of more simple branching structures that compare best with the natal down feathers of modern birds. It still has not been determined whether or not the structures on *Sinosauropteryx* are exactly the same as bird feathers, so they are often referred to as "protofeathers". No matter what you call them, they probably served to insulate the little dinosaur from cold and heat. This suggests that *Sinosauropteryx* and its closest relatives were probably warm-blooded animals, just like most birds and mammals.

Rappresentazione pittorica di Caudipteryx zoui. *(Disegno di Michael Skrepnick).*

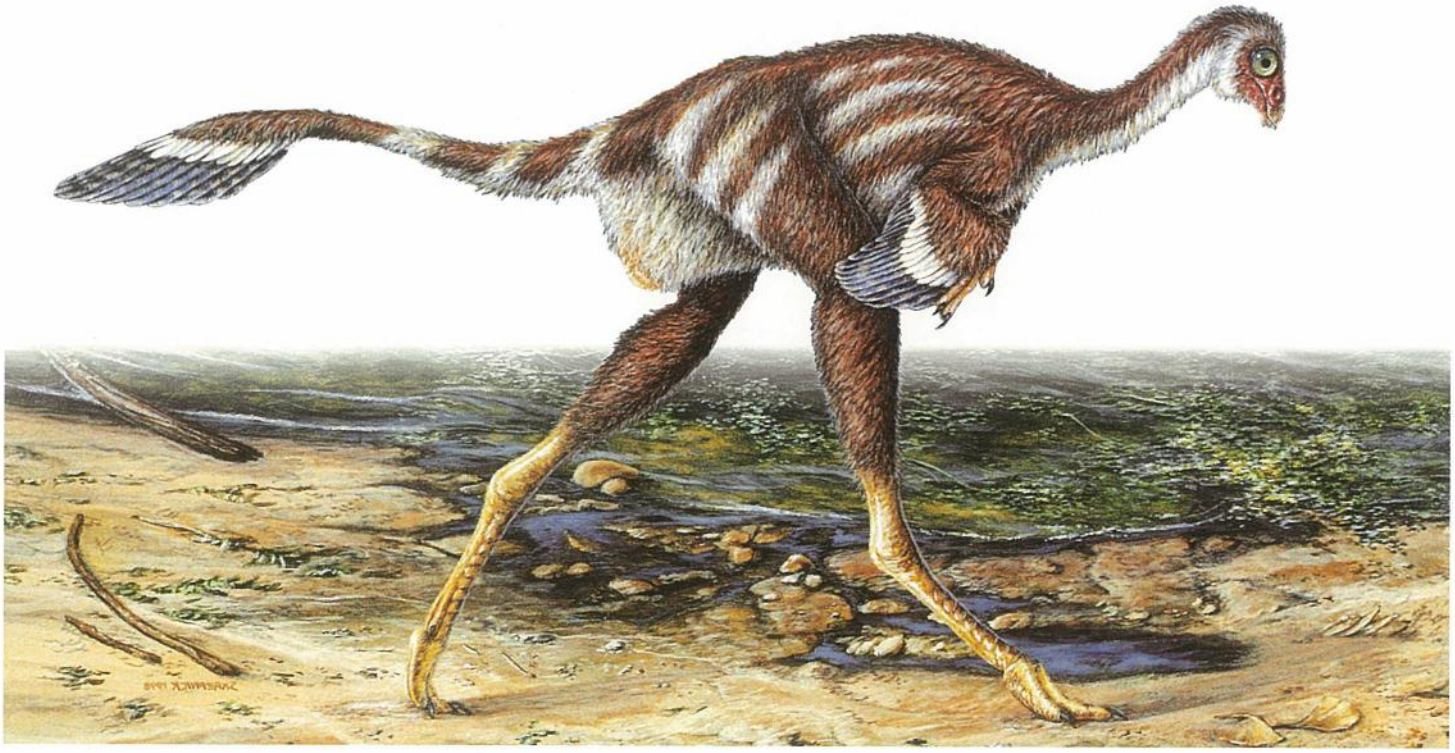
Pictorial reconstruction of Caudipteryx zoui *(Drawing by Michael Skrepnick).*

Pagina accanto, i lunghi denti aghiformi del Caudipteryx zoui *conservati al Museo Geologico Nazionale della Cina.*

Opposite, the long, needle-like teeth of Caudipteryx zoui *in the National Geological Museum of China.*

The area in Liaoning Province where *Sinosauropteryx* was found is extremely rich in 140 million year old fossils of all kinds (plants, clams, snails, shrimp-like conchostrachans, insects, fish, frogs, turtles, lizards, pterosaurs, crocodiles, dinosaurs – psittacosaurs, sauropods, therizinosaurs, dromaeosaurs, *Protarchaeopteryx*, *Caudipteryx* – birds and mammals). It is unique because it is rare to find so many small, well-preserved fossils. Bird fossils of this age have never been found in such abundance anywhere in the world. Since 1994, more than a thousand specimens of *Confuciusornis* (named after Confucius, one of the most famous Chinese philosophers) have been found at the site. Compare this number with *Archaeopteryx*, of which only eight specimens have been collected since 1861. We know that *Sinosauropteryx* was a meat-eater because of its sharp teeth and claws. In addition to that, two of the specimens have stomach contents! One ate a lizard just before it died, and the other ate a small mammal. The fossils are so well preserved that we even know *Sinosauropteryx* laid eggs because there is a pair of eggs in one of the specimens. They are positioned far back within the body cavity – too far back to have been stomach contents. The evidence suggests the eggs would have been laid two at a time. However, the mother lay more than two eggs in a nest, so she must have rested between laying each pair while the next two eggs were being covered by eggshell in her body.

During the 1970s, palaeontologists became more interested in the origin of birds than they had been for half a century. Controversy developed as some scientists championed theropod dinosaurs as the ancestors of birds, while others felt birds evolved from ancient crocodiles, thecodont reptiles like *Ornithosuchus*, or protorosaurians like the Italian *Megalancosaurus*. *Sinosauropteryx* became the focal point for the debate within months of its discovery. Some argued that the filaments on the outside of *Sinosauropteryx* were not related in any way to feathers, and one group came up with an elaborate scheme to identify them



Sotto, insetto e pesce provenienti dal famoso giacimento di Sihetun.

Below, insect and fish from the famous Sihetun site.

as collagen fibers within the skin of a frill. This hypothesis could not explain the presence of the fibers over the rest of the body of *Sinosauropteryx*, and the likelihood of preserving collagen fibers in this way was seriously thrown into doubt when two more specimens of *Sinosauropteryx* were discovered with the same body covering.
My Chinese colleagues are industrious, and do not wait around quietly while others are arguing over their specimens. They went out and found more evidence. The first was a new species of dinosaur with complex bird-like feathers. Ji Qiang and Ji Shuan named this one *Protarchaeopteryx*. Opponents to the hypothesis of a theropod origin for birds agreed that this was a dinosaur. However, they felt that the dinosaur had fallen on

Esemplare di pesce rinvenuto a Liaoning, ora conservato presso il Museo Geologico Nazionale della Cina.

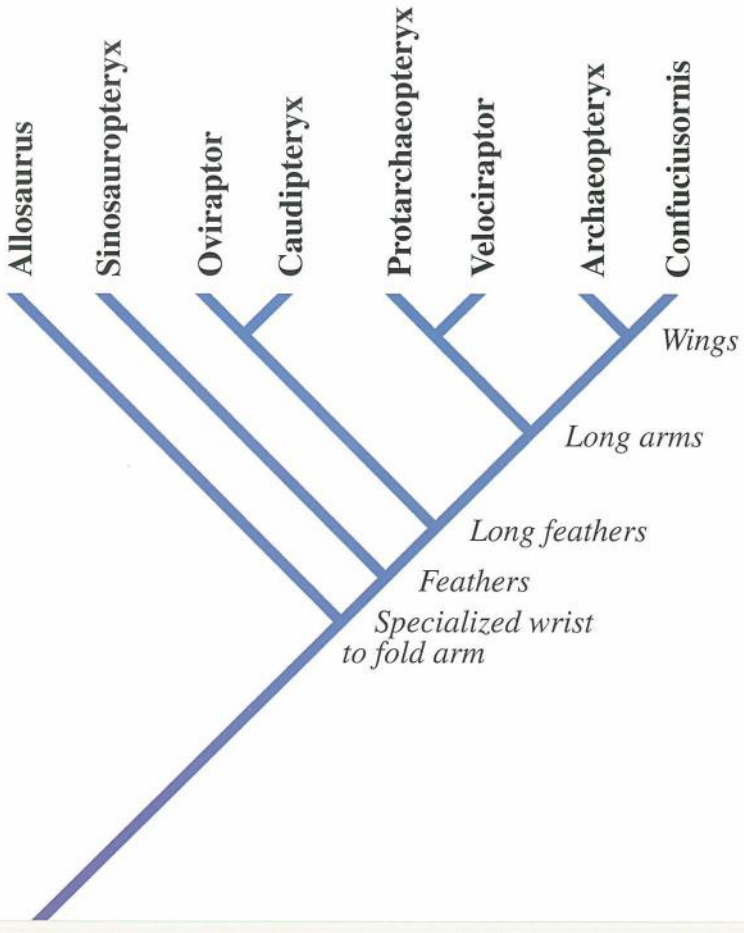
Fish specimen from Liaoning in the National Geological Museum of China.

top of a bird and that the feathers did not belong. Closer examination showed that the quill-like feathers were attached to the end of the tail, and that downlike feathers covered the rest of the body. Two more specimens were then discovered, one while we were in Liaoning.
Just before Christmas in 1997, I went back to China with a technician (Kevin Aulenback) to help Ji and Ji write the scientific paper on *Protarchaeopteryx*. We discovered that the two new specimens represented a third species of feathered dinosaur. Unlike *Protarchaeopteryx*, most of the teeth had been lost so that there were only four peculiar hooked teeth at the front of the upper jaw. We named the new animal *Caudipteryx* (which means "tail feather") because of the long bird like feathers at the end of the tail. The

Sotto, grafico che riproduce la linea evolutiva morfologica del passaggio dai dinosauri agli uccelli.

Below, diagram showing the morphological evolution in the transition from the dinosaurs to birds.

arms on this animal are short, but they have long feathers that make them look like short wings that would have been incapable of flight. Although we carefully considered the option of this animal being a bird that had lost the ability to fly, this idea proved to be unacceptable because there are too many other characters in the skeleton showing *Caudipteryx* was more primitive than *Archaeopteryx*. In other words, *Caudipteryx* was a ground-dwelling dinosaur that had started to develop structures that would eventually become wings.
Although the mystery of the origin of birds has been solved to the satisfaction of most scientists, controversies do not end overnight. Opponents of the theory of theropod ancestry claim that feathers evolved for the purpose of flight, so any animals that have feathers must either be a flying animal, or one that has lost the ability to fly. In their opinion, *Caudipteryx* and *Protarchaeopteryx* must be birds, not dinosaurs. However, it is highly unlikely that something as complex as a feather could have suddenly appeared when the ancestral bird "decided" it needed them for flight. It is far more likely that they were present in bird ancestors where they were being used for some other purpose. Once the ancestor had feathers, they could slowly be adapted for the complex function of flight.
Long before the Chinese feathered theropods were discovered, palaeontologists like Robert T. Bakker claimed that we would eventually find feathers on theropods. His reasoning was simple-feathers had to appear in the ancestors of birds, and theropod dinosaurs were the most likely ancestors of birds. He also felt that dinosaurs were warm-blooded, and because feathers are excellent for insulation it makes sense that they evolved to keep small dinosaurs warm. The discovery of feathers in dinosaurs did not come as such a big surprise to those scientists who already believed that birds evolved from dinosaurs.
Those scientists who now claim that a feather is the character that defines a bird are potentially causing an enormous problem for palaeontologists. Although this is a simple way to separate the two groups of animals, feathers are only rarely preserved in the fossil record. That is why palaeontologists have had to rely on features of the skeleton. These characters generally relate to changes in the skeleton that allowed birds to fly and perch. When we analyzed the systematic position of *Caudipteryx*, we used more than seventy-five anatomical features that characterize the transition from dinosaurs into birds. In all but two of these characters, we were able to show that *Caudipteryx* is more primitive than *Archaeopteryx*. This strongly suggests that *Caudipteryx* is unlikely to have evolved from a flying animal like *Archaeopteryx*. Because *Archaeopteryx* is by definition the earliest bird, and represents the most primitive animal of this lineage to have attained flight, then *Caudipteryx* cannot be a bird.
Animals like *Caudipteryx* and *Protarchaeopteryx* have many characters that were previously used to separate birds from dinosaurs. Those who are arguing that birds could not have come from dinosaurs have also argued that some of these characters are not found in birds. For example, theropod dinosaurs and birds are the only animals known to have bony extensions of the ankles that cover the front of the lower part of the lower leg (tibia or "shin" bone). This should be very powerful evidence that birds arose from dinosaurs. However, those who have argued against dinosaur ancestry have claimed that the extension of the ankle is not the same because it arises from a different anklebone. In dinosaurs it is an extension of the astragalus, but they claimed that it was an extension of the calcaneum in birds.
It is difficult to determine whether or not their claim is true in modern birds because all of these bones have fused together. However, if *Caudipteryx* and *Protarchaeopteryx* are birds, as these scientists claim, then there is no question that the ascending process arises from the



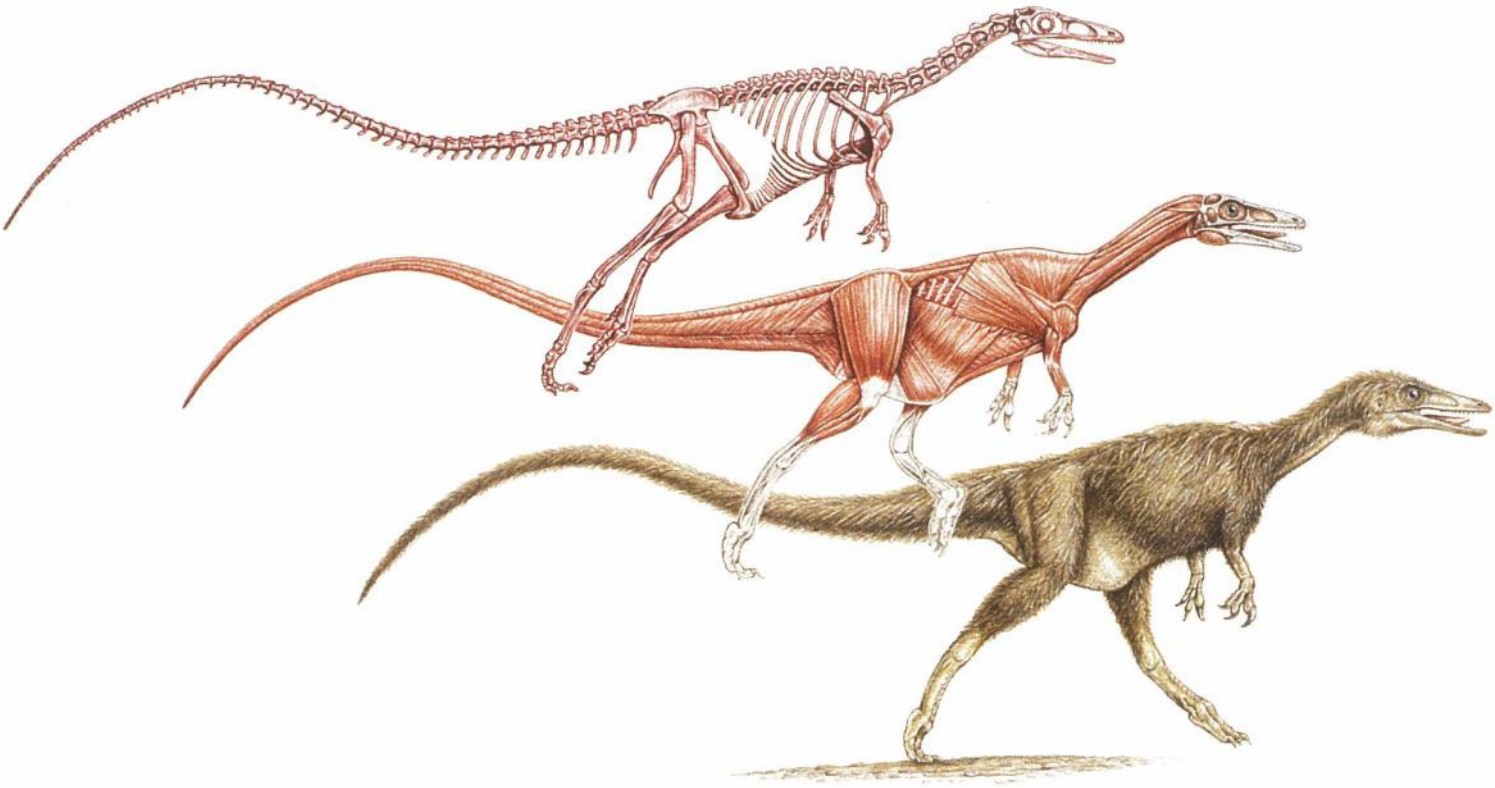
Ricostruzione pittorica di Sinosauropteryx prima. *(Disegno di Michael Skrepnick).*

Pictorial reconstruction of Sinosauropteryx prima *(Drawing by Michael Skrepnick).*

astragalus (and not the calcaneum). In other words by accepting the idea that *Caudipteryx* and *Protarchaeopteryx* are birds, they are effectively accepting the idea that birds evolved from dinosaurs. Character after character, this pattern holds true. Furthermore, if the "protofeathers" of *Sinosauropteryx* prove to be feathers in the true sense, that would suggest that all coelurosaurian theropods are birds using their definition. (*Coelurosauria* is one closely related group of the meat-eating dinosaurs that includes most of the small theropods, including *Sinosauropteryx*, *Compsognathus*, *Velociraptor*, and the Italian *Scipionyx*). Because *Tyrannosaurus rex* is a more advanced member of the same branch of the family tree as *Sinosauropteryx*, it would therefore be a bird. And it does not end there. We have no idea how far back feathers appeared in dinosaurs because they do not preserve easily. What if we find fossils of *Allosaurus* and more primitive dinosaurs with feathers too?

I am not advocating that *Tyrannosaurus* is a bird, but I am convinced that feathers do not make a bird. The evidence from the Chinese feathered theropods suggests that all of the coelurosaurian dinosaurs may have had feathers. Furthermore, they suggest that feathers may have evolved first for keeping the bodies of these generally small animals warm. Once they had feathers, they could be adapted into other functions. We have suggested that the long feathers on the arms and at the end of the tail of *Caudipteryx* may have been used for display. Dinosaurs, like their descendents birds, seem to have been very visual animals. Many developed crests, horns and other visible features for attracting mates, scaring off potential rivals, and so on. It is not surprising that as soon as feathers evolved they would start to use them for other functions. They are light in weight, and can be made colorful. Another suggestion is that the longer feathers on the arms may have been needed to cover eggs when the parents were brooding on their nests. At least four nests have been found in China and Mongolia with *Oviraptor* adults sitting over the eggs. Their outstretched arms do not cover all of the eggs, but with the simple addition of feathers behind the hand. No matter what the reason for elongating the feathers originally, once they had them they could provide some lift and maneuverability for a small running dinosaur. Selection could then work towards further elongation and the beginning of flight.

The Chinese feathered dinosaurs have been called one of the greatest palaeontological discoveries of the twentieth century. As we move into the twenty-first century, they will continue to provide information as we delve into the mysteries surrounding the origin of feathers, and the origin of bird flight. Specimens of *Sinosauropteryx*, *Caudipteryx*, *Confuciusornis* and *Protarchaeopteryx* from the National



Riproduzione grafica di un dinosauro pennuto della Cina. (Disegno di Renzo Zanetti).

Graphic reconstruction of feathered dinosaur of China (Drawing by Renzo Zanetti).

Geological Museum of China (in Beijing) were displayed at the Carnegie Museum of Natural History (Pittsburgh, USA), the Field Museum of Natural History (Chicago, USA), the Yale Peabody Museum (New Haven, USA) and at the headquarters of National Geographic (Washington, D.C., USA) during 1998 and 1999. The public and scientists will have one more opportunity to see these unique specimens when they visit the Royal Tyrrell Museum of Palaeontology in Drumheller (Alberta) during the summer of 1999. Afterwards, they will be put on display in a spectacular new dinosaur museum nearing completion in Changzhou in central China. One of the specimens of *Sinosauropteryx* from the collections of the Nanjing Institute of Geology and Paleontology toured through cities in Japan for most of 1999. Finally, another beautiful museum, devoted to the birds and other significant fossils of Liaoning, will open this year near the fossil sites outside of Beipiao.

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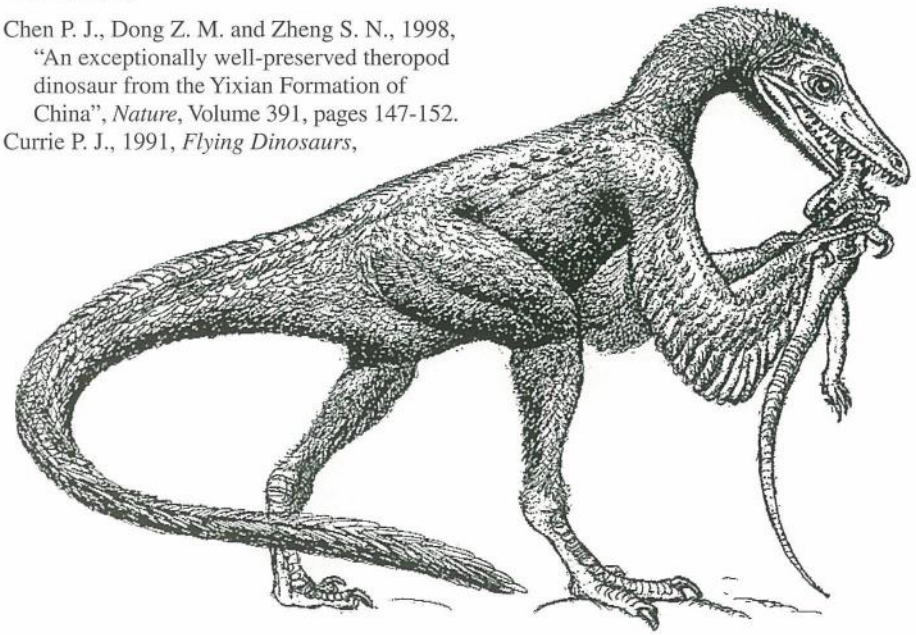

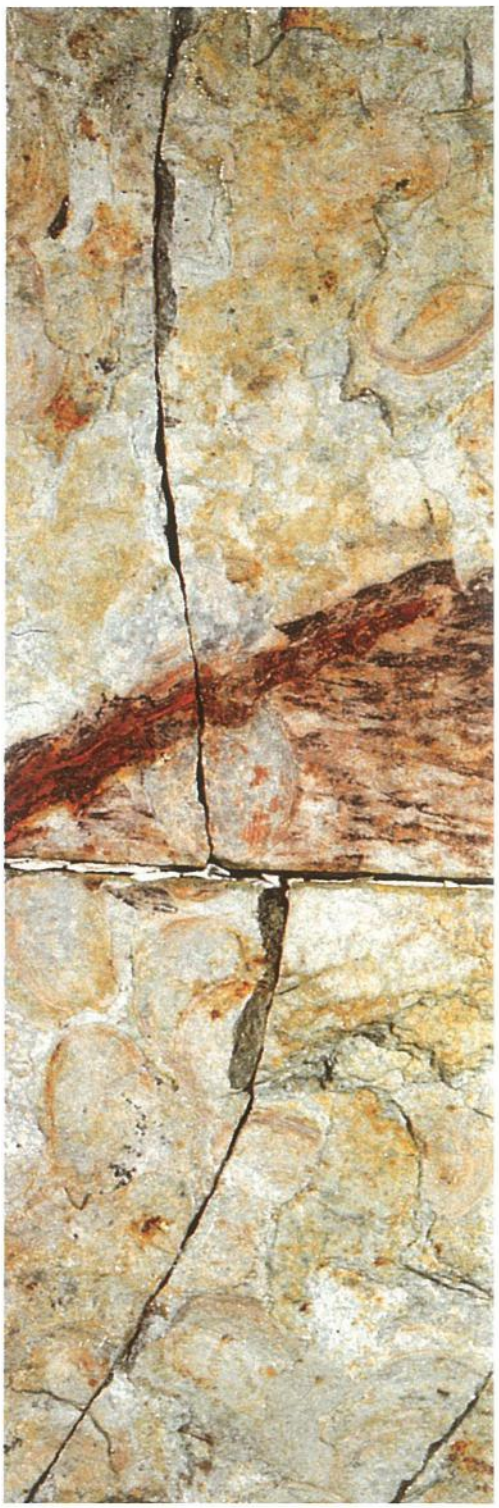

Le lunghe penne all'estremità della coda del Caudipteryx zoui, *conservate nel Museo Geologico Nazionale della Cina.*

Long feathers at the end of the tail of Caudipteryx zoui *in the National Geological Museum of China.*