

sequence) under a defined control element (developmentally or tissue specifically regulated), and the second gene encoding for the repressor which interacts with the former control element. The repressor itself is driven under the control of any normal cellular gene so that it is constitutively expressed and consequently the terminator expression is completely repressed only when the effector is added the expression of the gene will be induced. The third transgene is a recombinase, which will specifically recognize the marked sequences (located at both ends of the stuffer DNA sequences) and promote recombination between them. Several sequence-specific recombinases are known (e.g. the *cre-lox* system from bacteriophage P1 or the *flp-frt* system from the yeast). In the *cre-lox* system, the phage encoded recombinase CRE recognizes the defined DNA sequence LOX and, as a result, the DNA fragment flanked by the LOX sequences get excised out as a circle, leaving behind the rest of the parental gene sequences intact. In fact this technology has been used in both animal and plant systems to specifically turn on a gene in a particular tissue or at a particular stage of development

by modulating the expression of the recombinase, tissue specifically or development stage specifically by choosing the right sort of promoter. For instance, if the recombinase is engineered under the control of an 'embryogenesis' related gene (say, expressed only during late embryogenesis), the expression of recombinase will be confined to that period of time. Likewise, if the recombinase is under the control of a seed germination-specific gene, its expression will be confined to the germination process but not at the seed formation. The FLP-FRT system also works on similar principle as the CRE-LOX.

Thus, in a transgenic plant carrying all three transgenes, the expression of recombinase if confined to the seed germination period, the presence of an active recombinase at that time will lead to removal of the stuffer from the terminator gene and will result in its expression, when the effector is added. This in turn will end up in the failure of such seeds from germination. On the other hand, if the recombinase expression takes place during embryogenesis, the seed formation itself will be affected but once the seeds are formed it will have no effect on seed germination.

Although the above principles have been known for a while, how one puts them to use or misuse is the reason behind the controversy. The 'terminator' technology is feasible but whether one shall use it and with what consequences are the questions to be addressed. RAFL and other nongovernmental organizations have called for a global ban on terminator technology and the FAO Commission on Genetic Resources on Food and Agriculture was expected to condemn the technology. The long-term repercussions need to be carefully analysed before implementation of the technology.

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More about the 'feathered' theropod dinosaurs from China

A. V. Sankaran

No other extinct animal has sparked so many controversies about its life and extinction from earth as the dinosaur. Right from their evolution—whether or not descended from the reptiles, whether cold or warm blooded, and finally whether their extinction was gradual, induced by earthly causes, or sudden, triggered by extra-terrestrial agencies—in fact, every one of these has defied solution and still remains as enigmatic as ever before. It is no surprise, therefore, that their descendants, the birds, inherited, apart from their several skeletal and anatomical likenesses, some of the controversies too, particularly about the paternity with the dinosaurs. Now the detailed studies¹⁻⁴ on the 'feathered' dinosaurs, *Sinusauropteryx prima*, *Protoarchaeopteryx robusta* and *Caudipteryx zoui* discovered in Liaoning province of China since 1996, have brought out proofs to strengthen the dinosaur-bird descent and thereby adding

fuel for the ongoing controversy among the avian palaeontologists about birds' ancestry.

Liaoning province in northeastern China (Figure 1) has been home to several recent discoveries of well-preserved fossils of insects, fishes, reptiles, mammals and particularly many bird-fossils. *Confuciusornis sanctus*, a pigeon-sized bird fossil was discovered here in 1994, in the Jurassic formations. This fossil, displaying a few bird-like features, till then believed to have evolved only during Cretaceous, startled many, as it dethroned *Archaeopteryx* as the earliest bird-fossil^{5,6}. Soon, discoveries of other fossils of birds—such as *Liaoningornis* and *Chaoyangia* followed from the same site. These had toothed jaw, like a reptile, and resembled *Archaeopteryx*, *Hesperornis* and *Ichthyornis*, discovered in Europe and USA⁷. Very recently, a few more feathered specimens, *Proto-*

archaeopteryx robusta and *Caudipteryx zoui*, apparently flightless birds, intermediate between *Sinusauropteryx* and *Archaeopteryx*, with clearly preserved feathers, have also been reported from here^{2,3,8}.

The dinosaur-bird link has been based essentially on several of the gradual modifications in the skeletal framework to enable flight and they were evolved over a period of time among the avian members (maniropteran theropods) of the *Dinosauria* that had divided into avian and non-avian lineages. The adaptations were essentially in the pelvis, hand (wrist and fingers), clavicle, and the tail; and the bones, overall, became hollow to lighten body-weight. Typical modifications were the enlarged claw on the second digit of the foot, development of disc-like bone in the wrist to enable flapping of wings, fusion of the clavicle to form the wish bone which has a vital

role in flight and the union of the tail bones into a stump or pygostyle to which the tail feathers are anchored. In recent years, several new finds with half-bird and half-dinosaur skeletal features have come up outside this classic Liaoning site also. *Rahona ostromi* from the late Cretaceous beds of Madagascar having distinct avian features (particularly of the early birds like *Archaeopteryx*) and retaining characteristics of its theropod ancestry (like the sickle claw on the second digit of the hind foot and the typically theropodan dorsal vertebrae)⁹ and the flightless *Mononykus* theropod and *Shuvuuia deserti* from the Mongolian Gobi desert¹⁰ as well as *Unenlagia comahuensis* in Patagonia, Argentina¹¹ are some of the occurrences outside China. Apart from these bone characteristics linking birds and dinosaurs, cladistic analysis or phylogenetic systematics (determination of evolutionary history of a group of animals by examining certain new genetically determined traits shared by its descendants¹²) also strongly support a dinosaur parentage for birds. However, one typical feature of the birds, their feathers, even in a rudimentary form, that could establish this link beyond doubt, were not noted in many of the theropod-

bird hybrids earlier reported, until these Chinese discoveries of 'feathered' specimens from Liaoning Province¹⁻³ in 1996. Detailed studies on these fossils, undertaken by Pei-ji Chen, Zing-ming Dong (Academia Sinica, Nanjing) and Shuo-nan Zhen (Beijing Natural History Museum) as well as by Ji Qiang and colleagues (National Geological Museum of China, Beijing), Phillips Currie (Royal Tyrrell Museum, Alberta, Canada) and Mark Norell (American Museum of Natural History, New York) were not published till January² and June³ this year and this long gap between the discovery and studies, had in the meanwhile, given rise to considerable speculation about these fossils and the feather-like structures on them.

Two almost complete skeletons of the theropod, *Sinusauropteryx prima*, were the first among the 'feathered' specimens to be unearthed. A local farmer who happened to dig them out from Jian Shangou-Sihetun area in Liaoning province, sold them to institutions at Nanjing and Beijing. These fossils were found embedded within volcanic sediments intercalated in the basal part of Yxian formations made up mostly of andesites, andesitic breccia, agglomerates and

basalts. A few more feathered fossils—*Protoarchaeopteryx* and *Caudipteryx* were soon discovered from the same area from beds underlying the Yxian formations. Based on established palaeontological ages of other co-existing fossils in these formations, the age of the 'feathered' theropods was fixed to early Cretaceous period, but radiometric data assigned them to late Jurassic and early Cretaceous (165–97 million years ago). The specimens, which ranged 680 and 1200 centimeters, were those of fully-grown animals, with very long tail; surprisingly, two specimens of *Sinusauropteryx* exhibited well-preserved eyes and even some of the soft tissues, out of which, the lungs have been identified¹³. One of them also showed remnants of the last meal it had consumed—a complete skeleton of a lizard exactly in the region of the stomach; also, the find of a pair of eggs in the fossil's lower abdomen pointed to the animal's sex and its habit of laying, probably, two eggs at a time. In size morphology, these specimens are comparable to *Compsognathus* described from Germany and France as they shared several features like toothed jaw and other skeletal characteristics, particularly the large skull and short forelimbs of *Compsognathus*.

Chen and colleagues described² the fossilized feather-like features seen on *Sinusauropteryx* specimens they studied as *integumentary structures*. These are seen to run along the crest of the neck and back and also along the dorsal and ventral margins of the tail (Figure 2); and in the second specimen, they are seen to cover the rear half and sides of head and back, apart from neck and tail and also portions of the upper arm (humerus) and forearm (ulna). A narrow and continuous gap is observed all along the length of the body between these integumentary structures and the underlying bones which possibly correspond to the thickness of the skin and muscles in the region; as in modern animals, this gap is seen to gradually reduce towards the tail. The authors describe these structures as soft and pliable, arranged in some places in sinuous pattern and tangled in some areas. The thickest strands among them are thicker than those in majority of mammals, and in length, they vary from about 5.5 mm near the skull and lengthen near the shoulder and distal

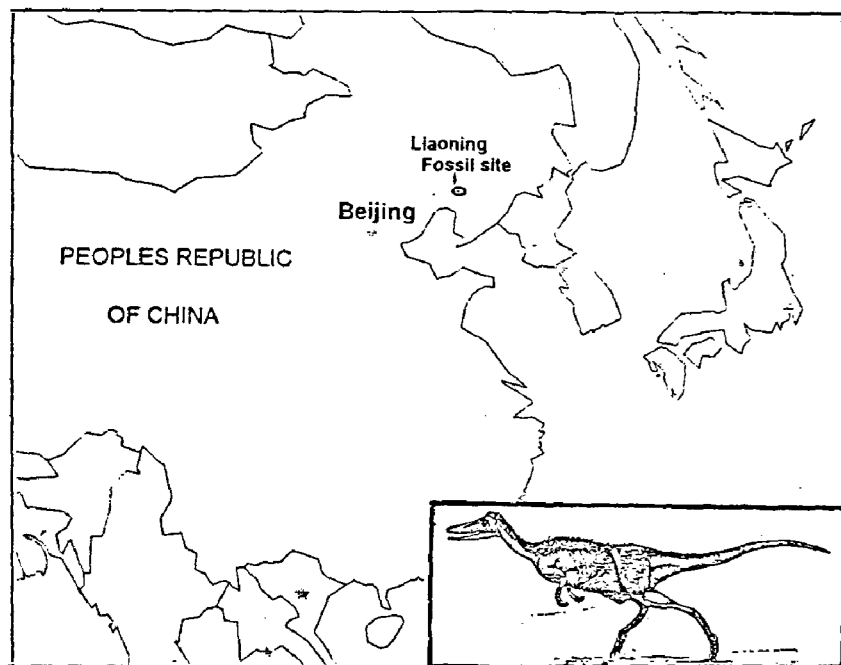


Figure 1. Map of Chinese Republic showing the site of the bird-fossils *Sinusauropteryx*, *Protoarchaeopteryx* and *Caudipteryx*. Inset: A reconstruction of *Sinusauropteryx prima*.

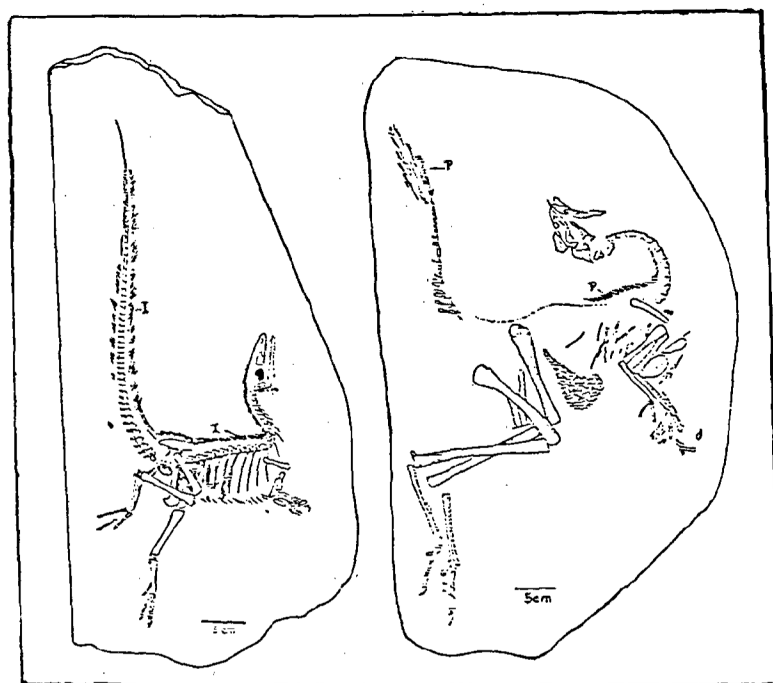


Figure 2. Skeletal reconstruction of (left) *Sinusauopteryx prima*, showing the integumentary structures (I) along head, back and tail and also faint traces of abdominal soft tissues, seen as dark pigmentation, (right) *Caudipteryx zoui* with plumulaceous feathers (P) on the tail and neck (Source: refs 2 and 3).

portions of the tail to as long as 40 mm. Studies³ on the later finds of *Protoarchaeopteryx* and *Caudipteryx* by Ji Qiang *et al.* have also brought out details of the feather-like features on these bird fossils and they have described them as undoubtedly plumulaceous feathers, attached to their chest, thighs and typically clumped on the tail and in lengths up to 130 mm (Figure 2).

Fossilization, mostly silicification of soft tissues, in nature is rare but not impossible. Under favourable environment and chemistry at the site of the animal's burial, these tissues can get preserved. Good examples of such preservation are seen in fossils of *Sipionyx samniticus* (a theropod dinosaur) from Italy where 'shallow lagoonal environment, affected by cyclic periods of low O₂ levels, led to exceptional preservation of soft tissues'¹⁴ and among the fossil-finds from Chinese Yxian formation site where, prior to fossilization, many of the animals killed by volcanoes were buried *en masse* in a lake bed and before they could rot, covered by a blanket of volcanic ash (seen today as tuffaceous sedimentary rocks), thus providing an ideal setting for *in situ* preservation of soft tissues¹⁵. Preservation

of similar integumentary structures and soft tissues has been noticed earlier in specimens of an Ornithomimosaur (*Pelecanimimus*) from Spain¹⁶, *Compsognathus* from France and Germany² and an unnamed theropod (maniraptor) from Brazil¹⁷, but their identity has been much questioned due to lack of supporting features, though this should not rule out that they may yet be integumentary structures or evolving 'feather' cover².

When the first announcement of the feathered theropod *Sinusauopteryx* from China was made in August 1996, it had galvanized many of the avian palaeontologists. Most of them, however, had no opportunity to examine the fossils closely, except photographs presented at the 56th Annual meet of Society for Vertebrate Palaeontology in October 1996. But, a team of experts—John Ostrom (Yale University, USA) and colleagues Alan H. Brush (ornithologist, University of Connecticut, Storrs), Larry D. Martin (palaeontologist, University of Kansas, Lawrence), Peter Wellnhofer (palaeontologist, Bavarian State Museum, Munich) examined the specimens, both megascopically and microscopically, and also made a field trip to the fossil-site in China,

early in 1997. Ostrom doubted if these could be 'feathers', as they lacked their characteristic branching patterns; according to Larry Martin, they could be frayed collagenous fibres within the skin and could have been part of the ridge or frill seen in some reptiles, like iguana, while Alan Brush felt they could perhaps be 'proto-feathers', if the structures were above the skin of the animal¹⁸. However, the presence of distinct feathers in the later specimens of *Protoarchaeopteryx* and *Caudipteryx* from the same site, must have, apparently, set at rest doubts about their identity as a sort of feather cover over the animal's body.

Chen *et al.* and Ji Qiang *et al.* admit that these structures on their theropod specimens are not comparable to typical flight feathers with characteristic barbs and hooklets, but claim that they may represent the plumules of 'modern birds with relatively short quills and long filamentous barbs'^{2,3}. These structures do not, either, indicate that they may have any role for display for courting or for flight. The development of flight feathers, Chen *et al.* observe, must have progressed gradually during succeeding geological periods and one cannot expect them to have fully evolved in the early ancestors of birds like *Sinusauopteryx prima*. They also argue that irrespective of the fact whether these species were endothermic or exothermic or intermediate between the two², the role of these integumentary structures could perhaps be more for body insulation, possibly they may be nature's preparation to enable these avian dinosaur species to maintain higher metabolic rates to take them to the skies later. 'What covered the ancestral stock of birds' may be 'evolution's first step to unfold aerodynamically designed flight feathers for transition from non-avian dinosaurs to modern birds'². These discoveries strongly strengthen (i) as Ji Qiang *et al.* observe, 'feathers and flight did not evolve together and these protofeather features in early theropods were more for purposes unrelated to flight (ii) the dinosaur-bird connection and the 'plumulaceous' feathers in some of the non-avian theropods provide unambiguous evidence supporting this connection.

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COMMENTARY

US visa denials: Revival of cold war paranoia?

R. Ramachandran

The issue of denials of US visas to some Indian scientists in the wake of the Indian nuclear tests in May has sparked considerable controversy. The obsession of the US with non-proliferation – only horizontal – in recent times has been such that some of the elements of its legislative and executive measures, ostensibly 'to prevent proliferation', have been mindless. The post-Pokhran denials of visas, denying Indian scientists entry into US government labs where they have been regular visitors for years, winding up collaborative projects which have nothing to do with nuclear science and asking Indian scientists working in these to pack up and leave clearly border on the extreme. (The Pakistani scientific community too is likely to have been subjected to similar restrictions.) Perhaps only at the height of the Cold War such embargoes were put on scientists from the Soviet Bloc. Indeed, some of the measures that have been invoked recently is a throwback to those times.

The episode would perhaps have not generated so much media and public interest had it not been for the fact that R. Chidambaram, Chairman, Atomic Energy Commission, was one of those affected by these embargoes. But from the perspective of academic freedom and unfettered pursuit of science, the Indian scientific community should view this development more seriously than is evident because of its implications for the future. In fact, there has been a greater supportive reaction from the US

scientific community than from here. Unless the issue is addressed at the appropriate international fora, such actions by governments could become more common.

As is by now well known from media reports, Chidambaram was to attend a meeting of the Executive Committee of the International Union of Crystallography (IUCr), a wing of the International Council of Scientific Unions (ICSU)¹, during 15-17 July at Arlington, Virginia. Chidambaram happens to be the Vice-President of the Executive Committee. On 29 June, Chidambaram applied for a

visa along with his 'diplomatic passport' at the US Consulate in Mumbai. In normal circumstances, it is learnt, issuance of visa against diplomatic passport is automatic and usually takes a day. In this case, while the visa was not refused, the passport and the application, along with the visa fee, were returned on 8 July. (The public statement by the US authorities that Chidambaram withdrew his application is untrue according to an AEC spokesman.)

On enquiry, the AEC was informally told by the consular official that as one of the key scientists involved in the

