Four-Winged Dinosaurs, Bird Precursors, or Neither?

KEVIN PADIAN

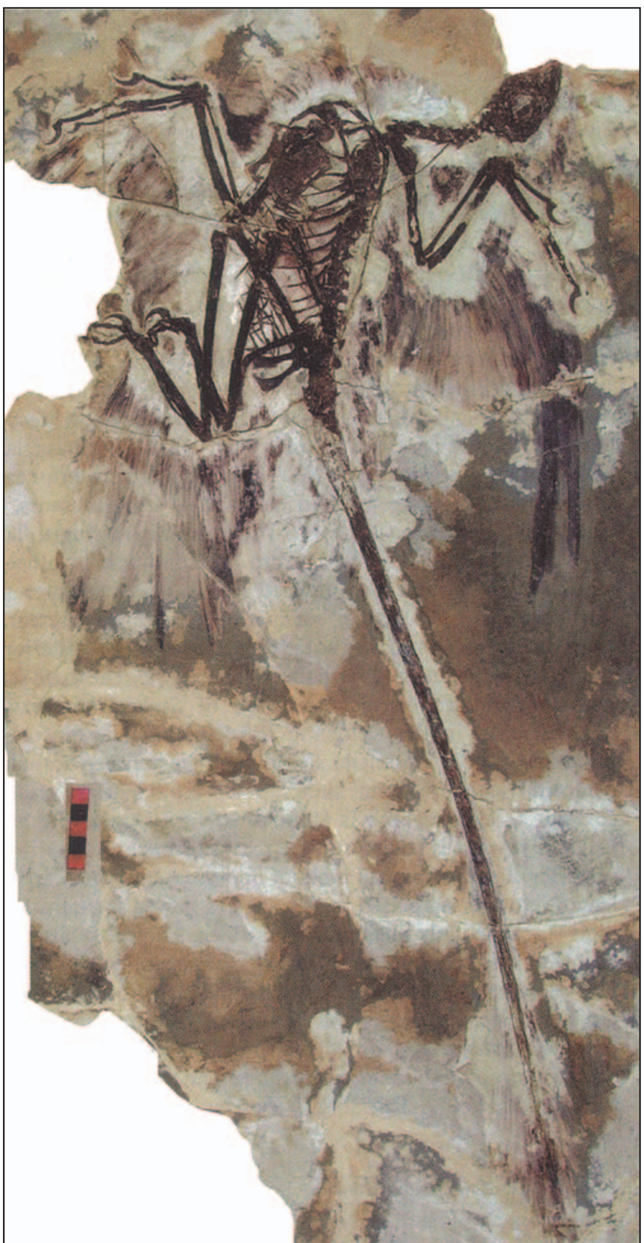

Figure 1. Skeleton of **Microraptor gui.** *Reprinted from Xu and colleagues (2003) by permission of* **Nature.**

New fossil specimens from the Early Cretaceous lakebeds of Liaoning, in northeastern China, are once again bridging and even overturning what we thought we knew about various aspects of vertebrate evolution. Or are they? The latest finds are of a small carnivorous dinosaur called *Microraptor gui,* which is very close to the first birds. This discovery, reported by Xu Xing and his colleagues in a recent issue of *Nature* (2003), is not the first discovery of *Microraptor.* But it is unusual in several respects. Most notably, the animal seems to have very long feathers attached to the hind limbs, as well as to the arms and tail. The authors infer that these feathers effectively created a "four-winged" gliding planform and that this should be seen as an incipient stage in the origin of bird flight. Moreover, they conclude, it supports the idea that bird flight began in the trees.

There are amazing features about this discovery, and if the claims for them pan out, the specimens are potentially as important as *Archaeopteryx.* The feathering in this nonavian dinosaur is more extensive than we've ever seen, and the size of the animal is getting closer to the optimal that is necessary to start evolving flight. It's an incredible discovery, the kind of thing that we've wished for—well, for centuries now.

That said, some inferences that the authors make aren't yet convincing, based on the evidence presented. This is a problem with the required brevity of articles in *Nature,* not necessarily with the evidence itself, but the case will have to be made in future articles. Not many scientists have seen these specimens yet (including me), and there hasn't been the opportunity for extensive review and discussion of many intriguing inferences. What are some of the issues that remain unresolved?

First, there's insufficient evidence of the attachment of these feathers to the hind limbs. The authors say that this is demonstrated by other specimens, and that may be so, but it's not visible in the published photos. There seems to be a gap between the vaned area of feathers that are near the hind limbs and the bones of the hind limbs themselves. The attachments may be clear in other specimens, but if so, it's too bad that we don't have good published photos of them. As Jim Cunningham of Cunningham Engineering Associates notes, "without information on attachment, we can't draw conclusions about transferring bending moments to the skeletal frame, and if we can't do that, then we can't assume that the hind wings were carrying flight loads."

Second, even assuming that the long feathers are attached to the hind limbs, the question of the use of feathers on the legs as a gliding surface is problematic. It cannot be assumed simply because feathers are present. Such feathers, if they are not organized into an airfoil with aerodynamic integrity, may slow its descent. But this is more like parachuting than gliding, such as we see in the "gliding" frog that uses its large feet to parachute and slow its descent. (These categories, parachuting and gliding, are not well defined, and much of this imprecision has to do with lift and drag coefficients.) A gliding squirrel or a gliding lizard has an airfoil with integrity, and so it can be used to guide the animal's flight. Xu and colleagues haven't yet established how (or that) the feathers could be arranged or controlled as an effective airfoil in *Microraptor.*

A corollary to this point is that there is no reason to assume that a gliding animal will necessarily evolve powered flight. Birds from *Archaeopteryx* onward have not used the hind limbs as airfoils and do not involve them in the flight stroke. So the leg feathering in *Microraptor* has nothing demonstrably to do with the evolution of the kind of flight that more derived birds use.

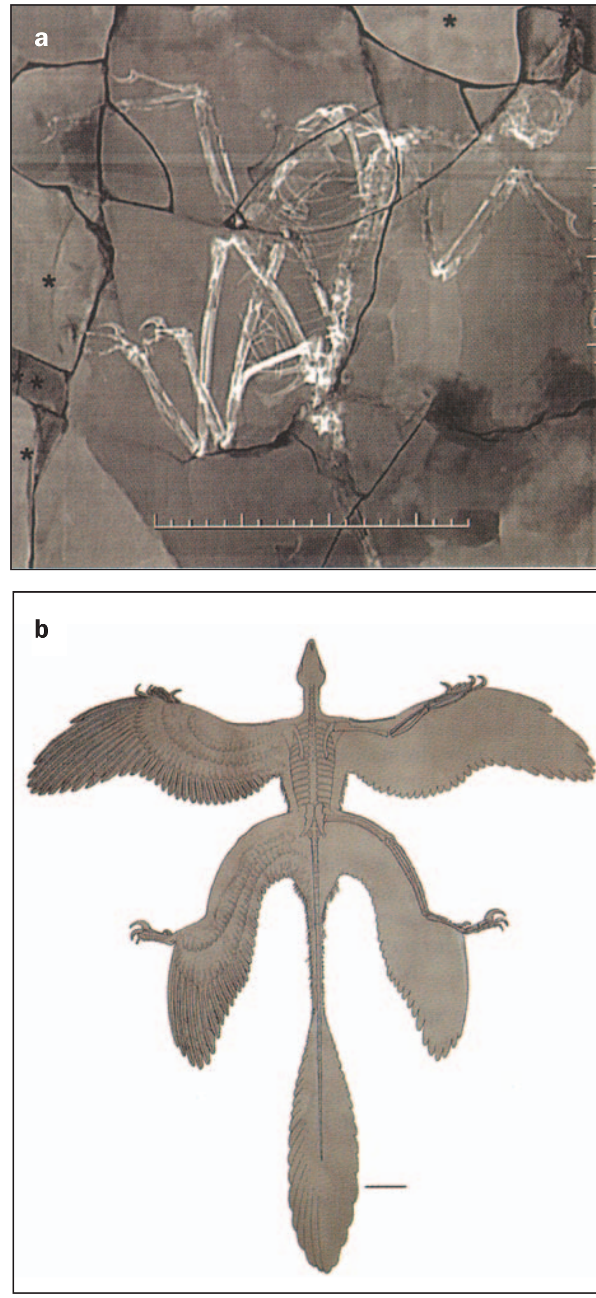

***Figure 2. (a) Computerized tomography image of the major part of* Microraptor gui. *(b) A reconstruction of* M. gui. *Reprinted from Xu and colleagues (2003) by permission of* Nature.**

This is as much a point of phylogeny (relationships) as of aerodynamics. Just how close is *Microraptor* to *Archaeopteryx* and the first birds? If it is not the closest known relative—and no one is so far substantiating that hypothesis, though *Microraptor* is probably not far removed from birds—then this feather arrangement could even be an independent evolution, for quite different functions. (As ornithologist Rick Prum noted in an accompanying commentary to the *Nature* article [2003], last year an even larger, as yet unnamed

Liaoning theropod was found with 13-centimeter-long feathers attached to its legs—and there was no claim that it used these to fly.)

Third, without comment, the authors show the hind limbs as sticking out to the side (figure 2b). This would be extraordinary because this position, in any known bird or other theropod, would quite likely dislocate the hip joint. (It has yet to be established that the hip muscles could even raise the leg into such a position.) Without evidence that the hip joint worked in a completely different way than in all other birds and theropods, it is difficult to see how the legs could be extended sideways so that the feathers could form a flight surface parallel to the wings. So a big question to answer is, if the "hind wing" surface is not parallel to the wings, of what use is it in lift? (It would certainly contribute drag.)

On the other hand, if the authors can demonstrate that this hip joint is unlike those of all other birds and theropods, then it would seem to be irrelevant to the evolution of flight in birds, because birds do not have this feature and do not use the hind limbs in flight. So *M. gui* would be a dead end in all senses.

Fourth, the authors say that the tibia is bowed, which would be extraordinary for any bird or theropod. When fossilized bones cross other bones, as the tibiae do here, they are often distorted, and these two bones seem to be distorted in different ways (figures 1, 2a). No animal that we know has a bowed tibia, and of what use would this be? It doesn't seem useful, even if their reconstruction of the "hind wing" pose (figure 2b) is correct. And if the animal wasn't capable of efficient terrestrial locomotion, as Xu and colleagues maintain, that would move it even farther from anything to do with the origin of birds.

Finally, the issue of whether birds evolved flight in trees or on the ground is effectively dead, because it isn't testable. We're not likely to find a fossilized bird in its fossilized tree, about to jump off a fossilized limb. The central problem of the evolution of flight is *how the flight stroke evolved,* because without it, flapping is not effective. (Also needed are an effective airfoil, a sophisticated neuromuscular apparatus, and an active metabolism for sustained flight.) As it turns out, considerable work has shown that the closest relatives of birds among the carnivorous dinosaurs had the same unique way of extending their forelimbs that birds have—but they were using this motion to trap prey instead of to fly.

One more thing: Is this animal conceivably built like a glider? There's a fairly rudimentary way to investigate, and it has a long history in the literature, particularly for estimates of the situation in *Archaeopteryx.* First, estimate the mass of the animal and determine its center of mass. Second, reconstruct the animal's pose in flight. Third, estimate the lift surface area and identify the center of lift. Fourth, determine whether or not the wing loading (mass over wing area) is commensurate with those of living gliders. Fifth, determine whether the center of mass is approximately over the center of lift. If either the fourth or fifth do not obtain, it will be difficult to argue for gliding abilities. (Note that this is not true of animals that flap rather than glide.)

Again, the authors are not necessarily wrong about all their inferences, and they may well be right about many of them (which would be very interesting). But many more questions need to be assessed. Nevertheless, this is an extraordinary find, and these specimens provide a lot of intriguing information about just how much equipment for flight was present in the small theropods that were closest to birds.

Kevin Padian (e-mail: kpadian@socrates.berkeley.edu) is a professor in the Department of Integrative Biology and curator of the Museum of Paleontology, University of California–Berkeley, CA 94720-3140.

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