Dinosaur Brooding Behavior and the Origin of Flight Feathers

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The origin of birds from within the group of theropod dinosaurs has been controversial because it is difficult to understand how wing feathers evolved through short intermediate stages before becoming long enough to generate adequate power and lift for flight. The "ground up" concept of flight evolution among cursorial dinosaurs can be criticized because there is no apparent selective pressure to drive the forelimb feather lengthening process through its earliest stages. Feather functions such as insect-trapping, hunting, and display have been proposed, but none of these require the feather length and shape that evolved by the time *Archaeopteryx* appeared.

We propose a mechanism to account for the forelimb and tail feather lengthening process, based on a behavior that exists in living birds—namely, brooding. Interestingly, despite the many known examples of modern birds that use their wing feathers in nesting and chick-rearing, there has been no previous proposal of brooding as a selective pressure in the evolution of flight feathers. We present fossil evidence that nesting and care of hatchlings could have been responsible for the development of long feathers on the forelimbs and tails of pre-avian theropod dinosaurs. It has been noted that oviraptorids incubated their nests in a posture strikingly similar to that of many modern birds, with breast and feet in contact with the eggs. However, gaps in the animal's coverage of its eggs were sufficiently large to allow solar-heating, wind-cooling, or rain wetting effects on the exposed eggs. Comparisons to modern birds demonstrate that these gaps could have been covered by wing and tail feathers. Thus, the evolution of long feathers on the forelimbs and tail base of theropod bird ancestors could have been driven, not by flight requirements, but by the advantage of decreased environmental stress on eggs and hatchlings. Significantly, this evolutionary process would have provided brooding advantages at every increment of feather lengthening. Even the first relatively short feathers would have offered increased protection for the young.

To assess whether brooding feathers could have originated among early non-avian dinosaurs, we undertook a comparative study of dinosaur and bird skeletal anatomy with emphasis on modern birds' nesting and brooding postures. We determined the extent to which theropod dinosaurs could adopt birdlike postures while incubating eggs and tending hatchlings, and concluded that the use of long forelimb and tail feathers for brooding could readily have existed even among early theropods. Furthermore, because the skeletons of these older theropods were conducive to brooding but not flying, forelimb and tail quill feathers may have evolved in these animals to the sizes and shapes seen in *Archaeopteryx* in the absence of flight, whereupon they were subsequently co-opted by *Archaeopteryx* or a similar creature for the additional purpose of flying.