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Scapular orientation in theropods and basal birds, and the origin of flapping flight

Phil Senter
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Basal birds such as *Archaeopteryx* and *Confuciusornis* are typically portrayed as flapping fliers. However, here I show that shoulder joint orientation in these animals prevented elevation of the humerus above the dorsum, thereby preventing use of the recovery stroke, an important part of flapping flight. In members of the clade Ornithothoraces, which includes extant birds and the extinct avian clade Enantiornithes, the shoulder joint is reoriented to permit elevation of the humerus above the dorsum, permitting flapping flight. Although basal birds may have glided, flapping flight began significantly later in avian evolution than has been thought.

Key words: Theropoda, Aves, *Archaeopteryx*, flight, flapping flight.

Phil Senter [phil.senter@lsco.edu], Department of Math and Science, Lamar State College at Orange, 410 Front Street, Orange, Texas 76630, United States.