Hummingbird jaw bends to aid insect capture

This tiny bird has a neat trick to trap flies in mid-air with its long nectar-seeking beak.

The upper jaws of birds, unlike those in many tetrapods, move relative to the skull and are often flexible along their length, whereas the lower jaw (mandible) is usually a rigid structure formed by the fusion of several bones, flexing only where it meets the skull. Here we describe a previously unnoticed mandibular bending movement in hummingbirds, in which the distal half of the mandible is actively flexed downwards and the gape widens to catch flying insects. The hummingbird is thought to have developed a long narrow bill as it specialized in feeding on floral nectar, but the bird's need to supplement its diet with insects must have contributed to the surprising flexibility of its jaw.

Hummingbirds (Trochilidae) have distinct specializations for nectar feeding[1], but they must also eat insects because floral nectars are deficient in essential amino acids[2,3]. However, it is not clear how these birds adapt their feeding mechanics to meet the demands that result from consuming both nectar and insects.

The dissimilarity in beak shape between hummingbirds and birds dedicated to aerial insectivory is striking. Birds that only eat flying insects typically have short beaks with wide gapes, which provide a broad surface close to the mouth for efficient capture and transport of prey[4,5]. By contrast, hummingbirds have long, narrow beaks that vary mainly in length and curvature.

We used high-speed video to study ruby-throated hummingbirds (*Archilochus colubris*), magnificent hummingbirds (*Eugenes fulgens*) and blue-throated hummingbirds (*Lampornis clemenciae*) as they hunted fruitflies (*Drosophila*, species unspecified). These hummingbirds catch their prey by flying at it with open jaws. During jaw opening, the distal half of the lower jaw flexes downwards (Fig. 1a). As the bird approaches prey, its jaw may bend without opening further, suggesting that bending is an active process and not a by-product of jaw opening (for movie, see supplementary information).

An intramandibular joint is found in other birds, such as the goatsuckers (Caprimulgidae), that feed exclusively on flying insects. In those cases, the joint flexes laterally, so that the lower jaw is bowed sideways by the opening of the mouth[6–8], and this enlarges the oral cavity. Presumably, this aids the capture of tiny prey. Dorsoventral flexion in the hummingbird mandible is mechanically and functionally linked to lateral jaw bowing. Our video recordings of hummingbirds reveal that flexion is accompanied by a bowing of the jaw that further widens the gape.

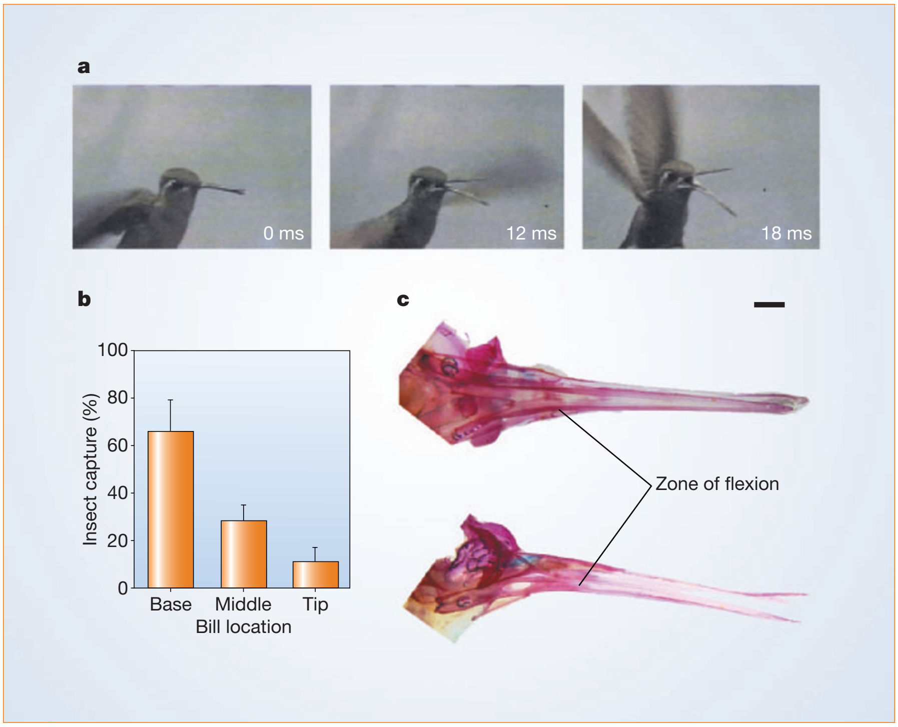

Figure 1 Intramandibular flexion during insectivory in hummingbirds. **a,** High-speed video sequence of an attack on a fruitfly (*Drosophila*; dark spot to the right) by a female magnificent hummingbird, showing the jaw opening, followed by bowing of the mandible at the base to widen the gape, and flexion of the distal half of the mandible. **b,** Success of insect capture (percentage caught) by a ruby-throated hummingbird in relation to where the prey first strikes the bill. More flies are caught at the flared base of the beak (repeated measures ANOVA; $F_{1,3} = 10.71$, $P = 0.047$); the few prey caught at the tip of the bill are often lost during transport to the mouth. **c,** Ventral (top) and right lateral (bottom) view of a cleared and stained (alizarin red, bone; Alcian blue, cartilage) ruby-throated hummingbird skull. No jaw joints are present; the mandible is a single, fused unit and has to deform in at least two dimensions in order to bend as seen in **a.** The intensity of the stain shows that the mandible is densely calcified up to the inflection point of dorsoventral bending. Scale bar: 1 mm.

This intramandibular flexion is used by the hummingbird only during insect capture. Most successful captures occur at the gape, rather than at the tip or middle of the bill (Fig. 1b). By widening the gape, mandibular flexion probably makes it easier for prey to enter the mouth and decreases the transport distance while increasing the beak's effective capture surface.

We know of no other tetrapod in which intramandibular flexion is achieved in two dimensions simultaneously, is actively controlled, and is evident during feeding. This flexion in hummingbirds is particularly remarkable because there is no detectable intramandibular joint in the hummingbirds we examined: all mandibular elements are fused (Fig. 1c). Flexion in the two directions simultaneously must therefore require complex deformation of thin bone.

This previously undiscovered ability in a bird that has been as intensively studied as the hummingbird suggests that the focus on adaptations for nectar-feeding may have obscured other important aspects of their evolution. Our results indicate that insectivory exerts a powerful influence on hummingbird form and function, despite their close evolutionary relationship with nectar-producing flowers.

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